Iron and Steel ENGINEER

ENGINEERING SERVICE TO THE IRON AND STEEL INDUSTRY SINCE 1907

EMPIRE BUILDING DECEMBER, 1945 PITTSBURGH, PA.

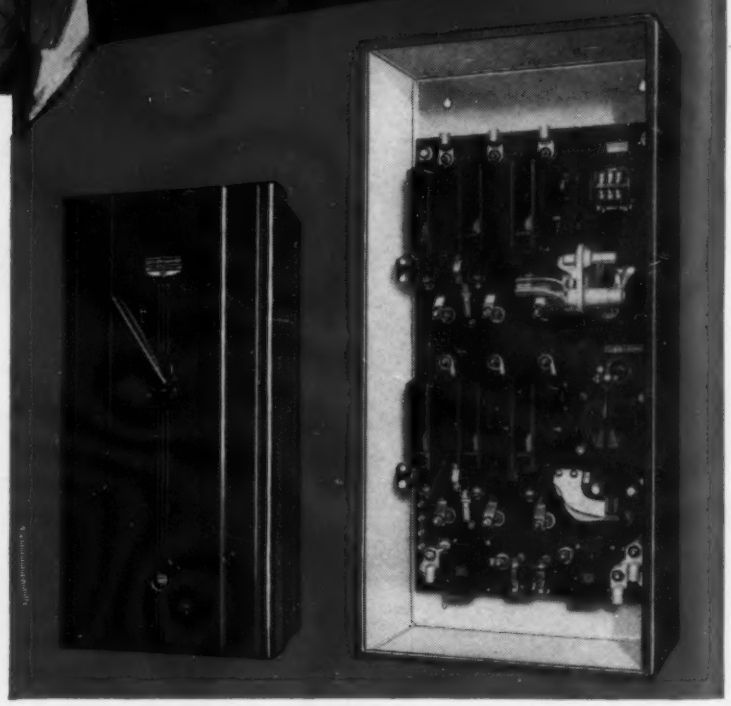
TECHNOLOGY DEPT

LIBRARY

WHAT SIZE PHASE?
From ingot to billet, to plate, to sheet, to foil . . . whatever you're rolling you can depend on Lewis for rolls that are right —right down the line.
LEWIS FOUNDRY & MACHINE
DIVISION OF
BLAW-KNOX COMPANY
PITTSBURGH, PA.
Also manufacturers of
ROLLING MILL MACHINERY
for the iron, steel and non-ferrous industries
LEWIS ROLLS

Cutler-Hammer Combination Starters

. . . A UNION OF CONVENIENCE, ECONOMY AND WORLD-FAMOUS ENGINEERING



Cutler-Hammer Combination Starters offer many advantages that production-minded executives and experienced electrical supervisors are quick to recognize. Combining motor control *and* safety switch in one compact case, they save just about half the time required for mounting and wiring separate units. They effect savings throughout their long life by providing greater convenience in operation and maintenance. They protect motors against overload but, through use of the famous Cutler-Hammer Eutectic Alloy Overload Relay, they do not needlessly interrupt production on harmless current surges. They provide the smooth trouble-free performance of Cutler-Hammer Dust-safe Vertical Contact motor control and a motor-circuit switch built to the same high standard of engineering excellence. CUTLER-HAMMER, Inc., 1269 St. Paul Ave., Milwaukee 1, Wisconsin. Associate: Canadian Cutler-Hammer, Ltd., Toronto, Ontario.

CUTLER-HAMMER
MOTOR CONTROL
C-H

Look for these superiorities in C-H Combination Starters

Eutectic Alloy Overload Relay
This famous engineering achievement utilizes a fusible alloy with unvarying characteristics. Grips tight till the danger point is reached, then releases instantly to cut motor off the line. Resets without delay.

Dust-safe Vertical Contacts
Assure full metal-to-metal contacts. No arcing; burning, pitting or welding. No dressing or filing.

Trouble-free Safety Switch
The motor-circuit switch in a Cutler-Hammer Combination Starter is built to the same high standard of engineering excellence as the motor control.

Plenty More Features

- General purpose and NEMA types 1A, 4, 5, 7, and 9 special service enclosures.
- Heavy-duty contactors, open and accessible. Pivoted construction and self-aligning armature eliminate sliding friction, assure positive, equalized contact pressure and quiet operation.
- Magnet coils, vacuum-impregnated, solid 100% filled. Easily accessible.
- Disconnects; side-operated safety switch; front-operated contactor type or thermal type circuit breaker.
- Low voltage control circuit from self-contained transformer.
- Vise-type main circuit fuse clips.
- Reversing or non-reversing.
- Cadmium plating or stainless steel metal parts protect against rust.

AN ACCOUNT THAT'S NEVER CLOSED

We're about to close another year, balance our books, take our inventory, report to our stockholders.

But there's one account we never close out—one we can't enter, audit—and then forget. That account is *friendship.*

At this pleasant time of the year, let's forget about business and think about friends. Let's thank God for our business friendships—and for the privilege of saying once more to all our friends

A Merry Christmas
A Happy New Year

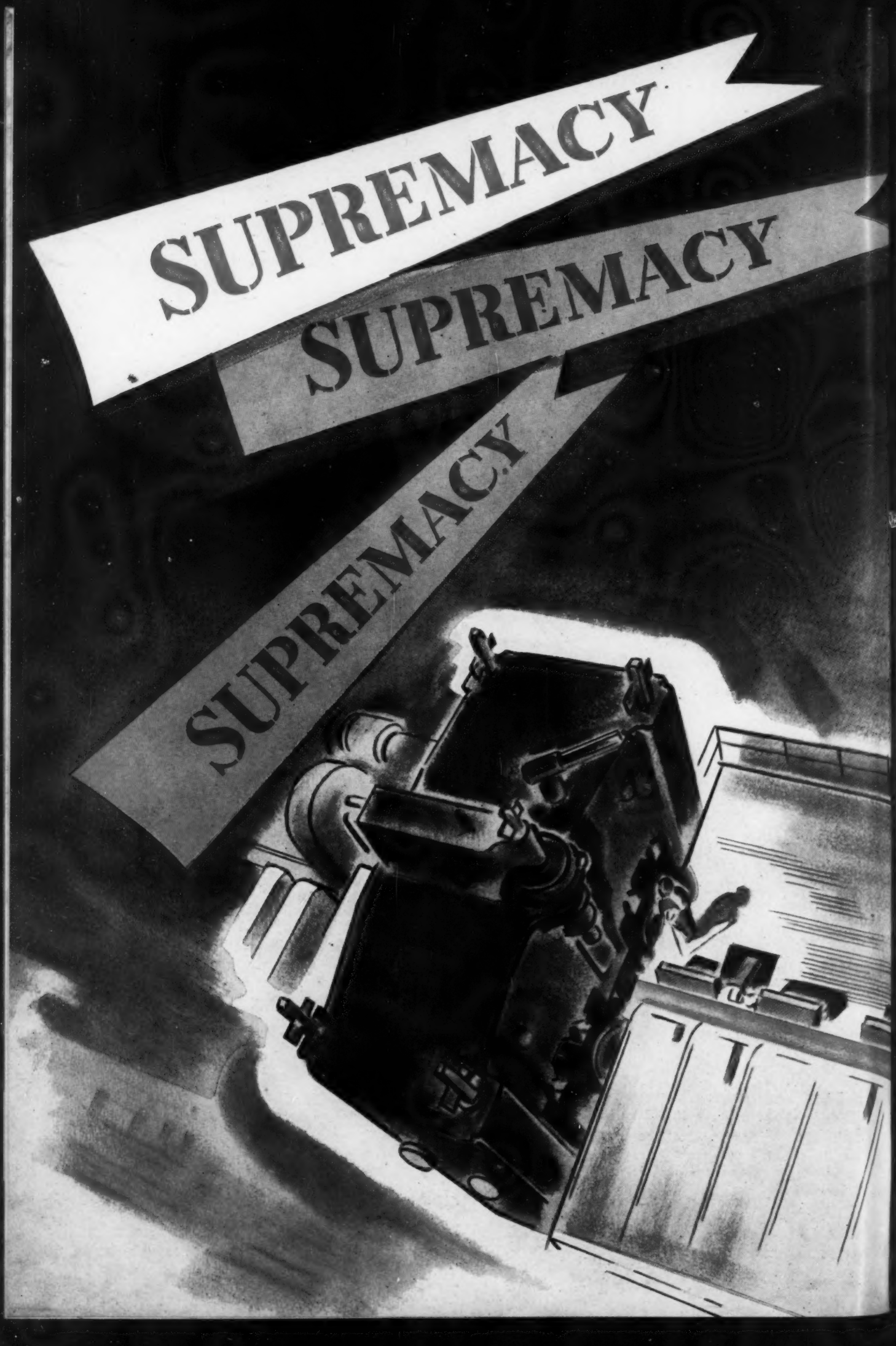
NATIONAL ROLLS

THE NATIONAL ROLL & FOUNDRY CO.

AVONMORE, PENNSYLVANIA

Manufacturers of: ALL GRADES OF CAST ROLLS • IRON & ALLOY IRON STEEL & ALLOY STEEL • HEAVY IRON & STEEL CASTINGS • ROLLING MILL EQUIPMENT

ARMY E NAVY


SUPREMACY
SUPREMACY
SUPREMACY

AETNA·STANDARD

SEAMLESS TUBE AND CONTINUOUS BUTTWELD PIPE MILLS

The Tubing Industry and Aetna-Standard have grown up together as partners in a great American enterprise.

The Aetna-Standard supremacy as a builder of tube mills began with R. C. Stiefel, who developed the first tube mill as a member of the firm of The Standard Engineering Co., Ellwood City, Pa., predecessor of The Aetna-Standard Engineering Company.

In the intervening 40-odd years, the tubing industry has co-operated with Aetna-Standard in developing new ideas, new methods, and new mills.

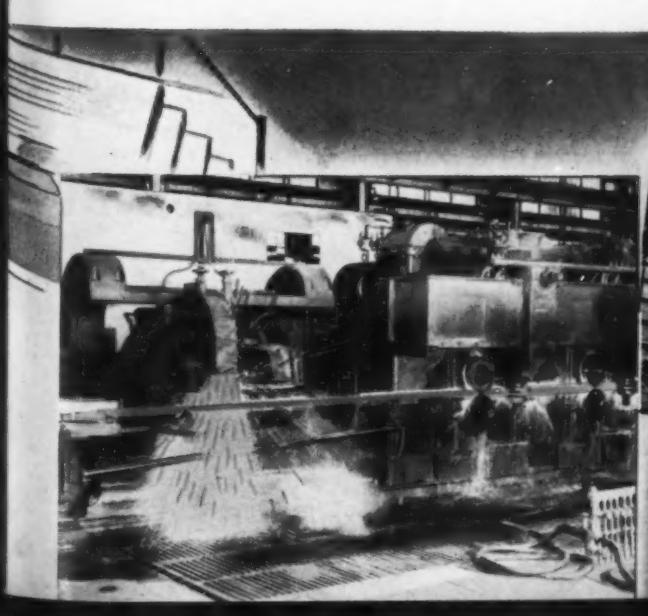
Tubes have increased in size and length — up to 50′ lengths and 24″ diameters. Instead of measuring a day's production in feet, modern Aetna-Standard mills make it possible to count in miles. Quality has steadily improved, yet operating costs have decreased.

As the world's foremost tube mill builder, Aetna-Standard has designed and constructed most of the seamless tube mills in this country and many foreign lands. Aetna-Standard is the only American company which has built seamless tube mills in the past 10 years.

The supremacy continues into the field of continuous buttweld pipe mills. Aetna-Standard has designed and built the mechanical equipment complete for 7 mills in the last 6 years.

To you who may be contemplating a capital expenditure for tube or pipe mill equipment, this supremacy is important. Aetna-Standard is the only company which has all the facts and figures you need to consider your investment in the cold light of costs.

Most important of all, Aetna-Standard is the only company which has engineered and built a complete seamless tube mill or a complete continuous buttweld pipe mill.

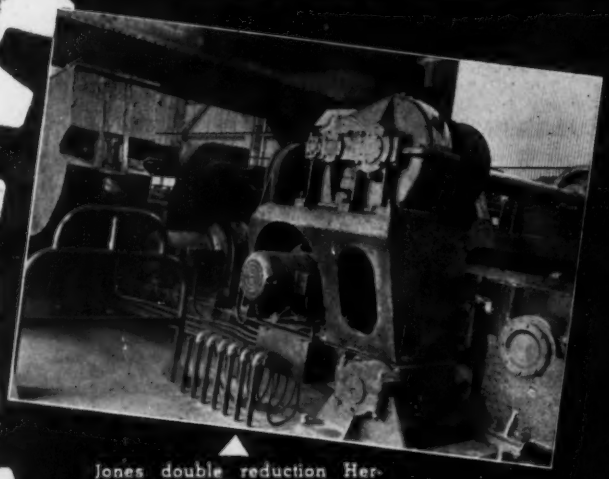


THE AETNA·STANDARD
ENGINEERING CO. — YOUNGSTOWN, OHIO

DESIGNERS AND BUILDERS to the Steel, Non-Ferrous and Chemical Industries.

ASSOCIATED COMPANIES:
HEAD, WRIGHTSON & COMPANY, LIMITED, THORNABY-ON-TEES, ENGLAND
JOHN INGLIS COMPANY, LIMITED, TORONTO, ONTARIO, CANADA

JONES DRIVES
in the Steel Industry



Jones double reduction Herringbone Reducer driving blooming mill slab pusher on runout table.

Carriage travel for cold strip processor driven by Jones worm gear.

Jones worm gear driving blooming mill crop conveyor.

Jones triple reduction Herringbone Reducer driving blooming mill shear approach table — adjustable side guards.

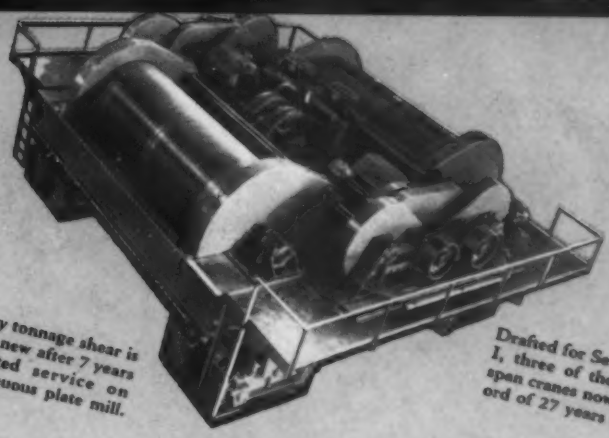
• There are many sound reasons why Jones Herringbone and Worm Gear Reducers have been selected for these and many other applications in the steel industry . . . reasons which we believe you will also find sound and convincing when you are considering your drive problems. In any case we shall be pleased to place complete information in your hands covering speed reducers and other Jones transmission products.

Jones

HERRINGBONE • WORM • SPUR • GEAR SPEED REDUCERS • PULLEYS • GEARS • V-BELT SHEAVES • ANTI-FRICTION PILLOW BLOCKS • FRICTION CLUTCHES • FLEXIBLE COUPLINGS

W. A. JONES FOUNDRY & MACHINE CO., 44[illegible] ROOSEVELT ROAD, CHICAGO 24, ILLINOIS

This heavy tonnage shear is as good as new after 7 years uninterrupted service on 100" continuous plate mill.



Drafted for Service in World War I, three of these 336 ton 90' 0" span cranes now have a service record of 27 years without furlough.

World's Largest Builder of the World's Largest Cranes

Alliance ladle cranes have an extra safety feature in the method of reeving hoist ropes... an Alliance patent.

ADLE CRANES • GANTRY CRANES •
RGING MANIPULATORS • SOAKING
IT CRANES • STRIPPER CRANES •
LAB AND BILLET CHARGING MACHINES
OPEN HEARTH CHARGING MACHINES

Sixty ton ingots ride to the plate mill in this giant Alliance Ingot Chariot.

Alliance has been building cranes and other mill equipment since 1901.

addition to multiple range tongs, there are many ique features on this new type soaking pit crane.

To grip, lift, and swing a 20 ton ingot at a radius of 28 feet, Alliance built 400,000 pounds of useful weight into this ingot charging machine.

ARMY E NAVY

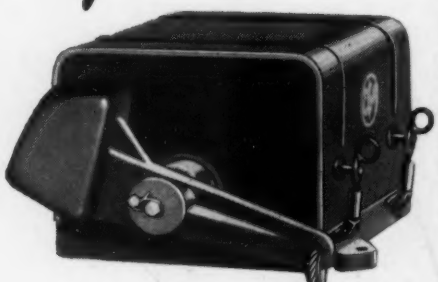
THE ALLIANCE MACHINE CO.
ALLIANCE, OHIO
PITTSBURGH, PA., OFFICE — 1622 OLIVER BLDG.

Alliance

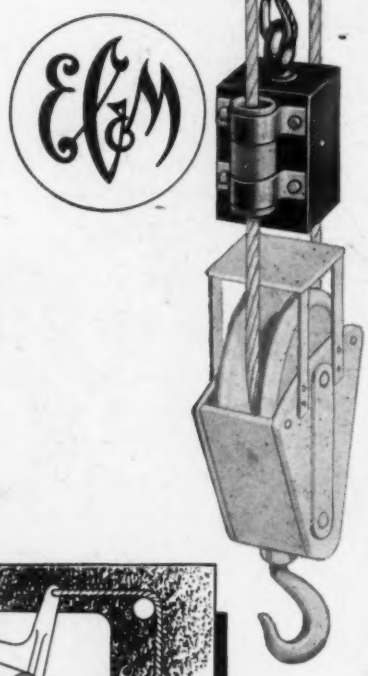
Improved Protection for CRANE HOISTS

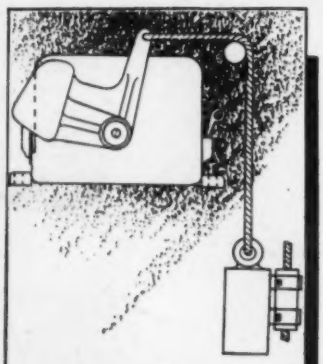
AGAINST OVERTRAVEL

with EC&M *SAFETY LIMIT STOP*

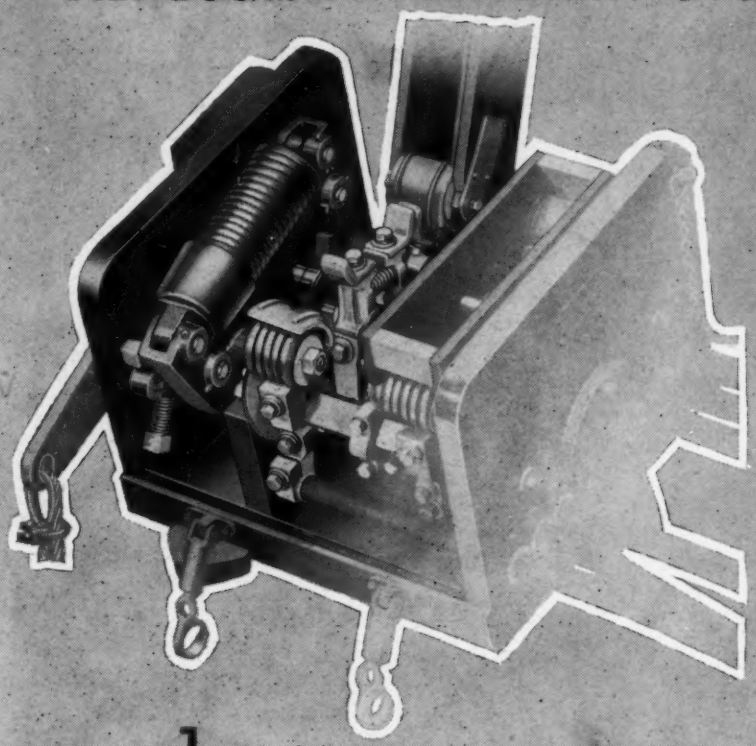


No. 20 Youngstown size; 100 H.P.; 230 volts; single motor rating. Also available in duplex style.





Optional Style— with offset weighted-arm which eliminates intermediate sheaves when Stop is not mounted directly over crane hook-block.



1 No lubrication required—Oilite bearings (with super-oilite on main bearings) are self-lubricating and long-lived. This means that the costly and sometimes forgotten item of lubricating maintenance is eliminated forever.

2 Compact—easy to mount—Reduced, overall dimensions—three convenient mounting holes, and but one suspended weight.

3 Small reset travel—High crane lifts are possible with the No. 20 because the amount of travel between "run" and "tripped" positions has been kept at a minimum.

4 High interrupting capacity—Two normally open and two normally closed contacts, mechanically interlocked and with wide, vertical opening, always assure positive interruption of the hoist motor current.

This No. 20 Youngstown Limit Stop can be easily installed on new or old cranes, either alternating or direct current operated.

Folder 1035 gives complete description. Write for your copy.

A Crane Without a Youngstown Is as RISKY as a Boiler Without a Safety Valve

THE ELECTRIC CONTROLLER & MFG. CO.

2698 EAST 79th STREET ★ CLEVELAND 4, OHIO

MESTA

ALL required tempers can be produced on Mesta High-Speed Twin Four-High Cold Skin Pass Mills. These mills feature new types of drives and control systems which maintain synchronization during acceleration, deceleration, and at normal operating speeds.

MESTA MACHINE COMPANY

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In operation and under construction

1710

NEW KOPPERS AUTOMATIC SELF-SEALING DOORS

DO AWAY WITH ALL ADJUSTMENTS TO SET SCREWS

450

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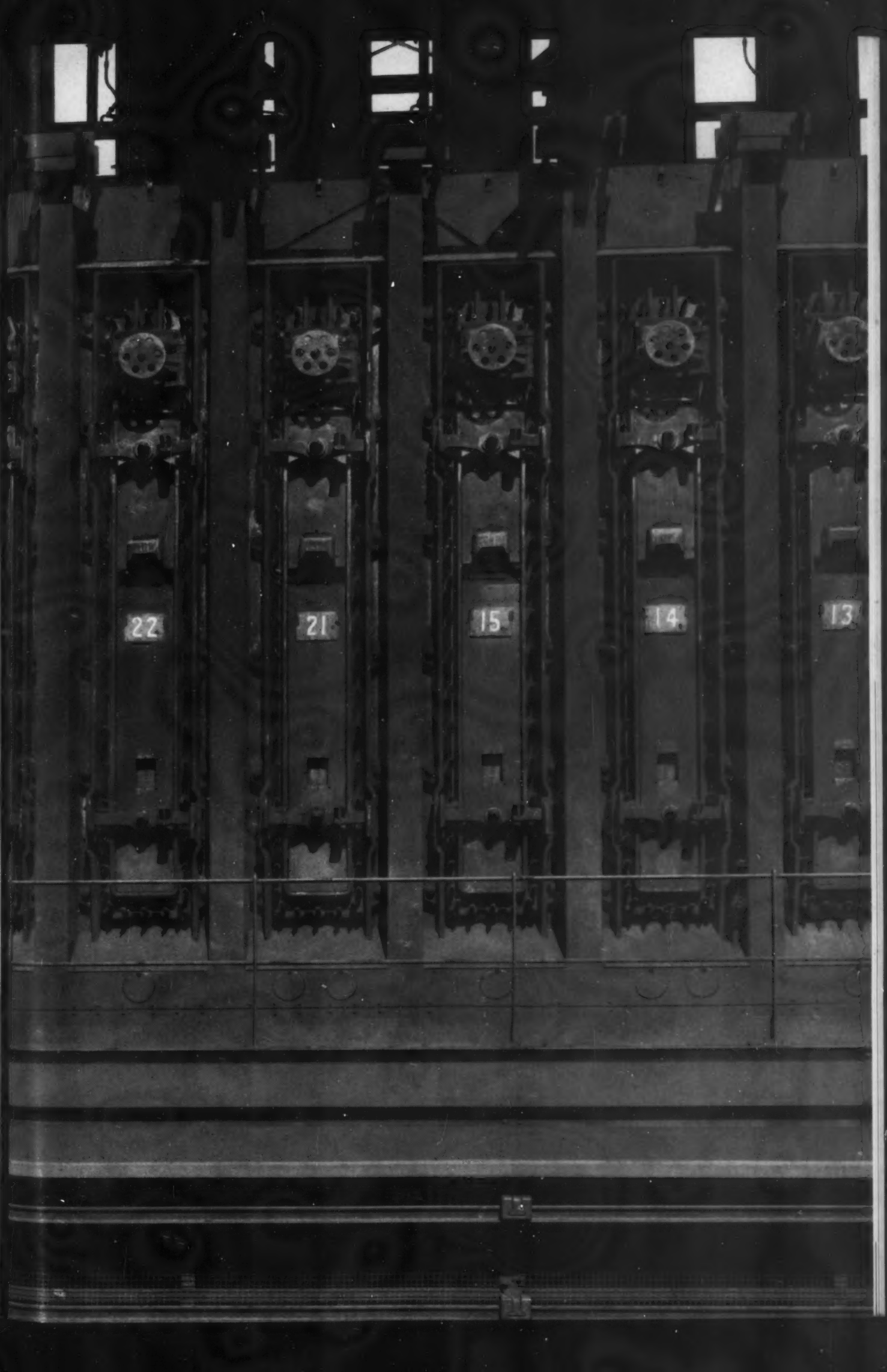
KOPPERS

The industry that serves all industry

In byproduct coke-oven design, Koppers leads

Buy Victory Bonds . . . and keep them!

KOPPERS COMPANY, INC., ENGINEERING AND CONSTRUCTION DIVISION, PITTSBURGH 19, PA.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In all types: Single Stand, One Way or Reversing, Tandem, Continuous, etc. For Carbon Steel, Alloy Steels, Copper, Brass, Aluminum and other Non-Ferrous Metals.

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"UNEFCO" Green Wabblers Grain and Chill · United Nickel Chill · United Moly. Chill · United Spec. Process UX Chill and Grain · H.D. Spec. Process · Lincoln Special · United Unidense · United Special Steel · United Carbon Steel · United Adamite · United VAN-X · United Super X · United Straight Chill.

Auxiliary Equipment

Ingot Cars
Manipulators
Edgers
Mill Tables
Transfers
Hot Beds
Structural Straighteners
Bloom Shears
Vertical Shears
Hot and Cold Saws
Rod Reels
Hot Strip Reels
Flying Shears
Shearing Lines
Slitting and Trimming Lines
UNIDRAW—Continuous Draw Benches
Steam Hydraulic Forging Presses
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Electro-Hydraulic Piercing Presses
Hydraulic Presses
Universal Couplings
Welding Manipulators
Plate and Squaring Shears
Precision Levellers
Cone Type Uncoilers
Coil Boxes
Upcoilers & Downcoilers (Strip)
Cold Strip Reels
Cone Worm Drives
Gear Reduction Units
Generated Gears and Pinions
Continuous Strip Picklers
Semi-Continuous Strip Picklers
Rotary Strip Picklers
Electrolytic Strip Cleaning Lines
Electrolytic Strip Tinning and Coating Lines
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The World's Largest Designers and Makers of Rolls and Rolling Mill Equipment

UNITED ENGINEERING AND FOUNDRY COMPANY
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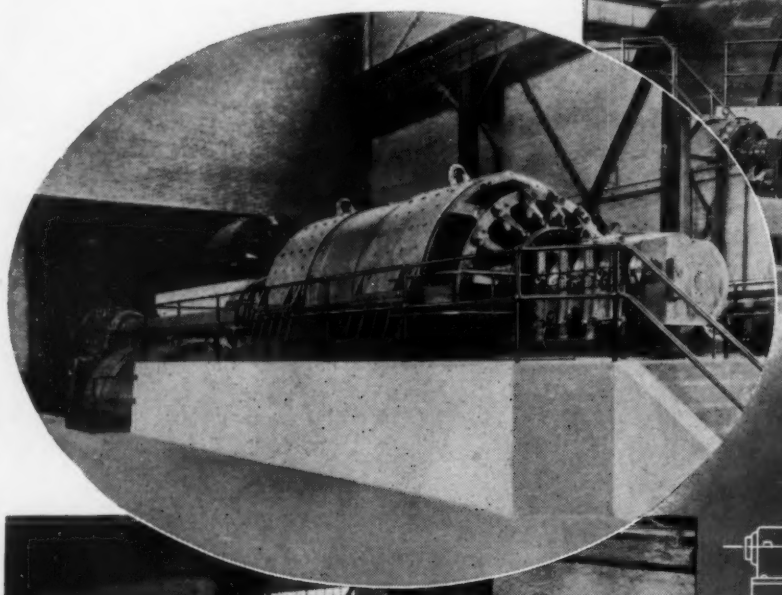
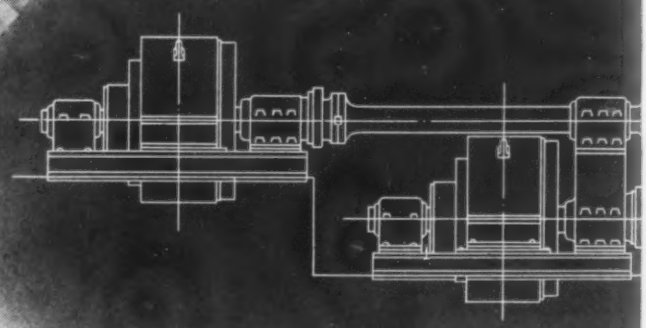
Plants at Pittsburgh · Vandergrift · New Castle · Youngstown · Canton
Subsidiary: Adamson United Company, Akron, Ohio
Affiliates: Davy and United Engineering Company, Ltd., Sheffield, England
Dominion Engineering Works, Ltd., Montreal, P. Q. Canada

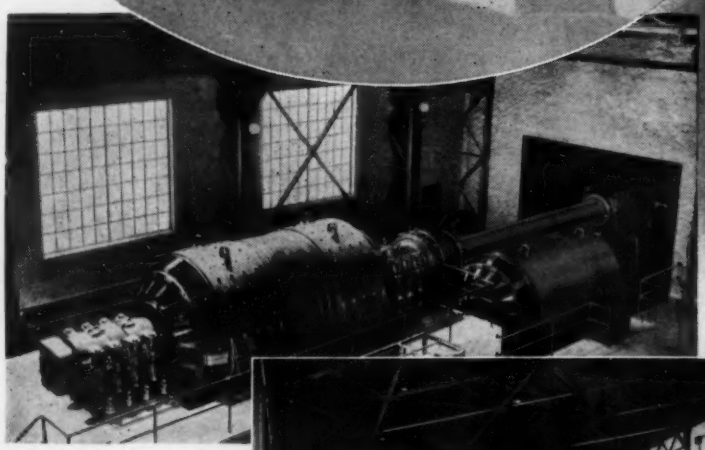
Westinghouse

10,000 hp Twin-Motor Double Armature Installation in a *Slab Mill.*

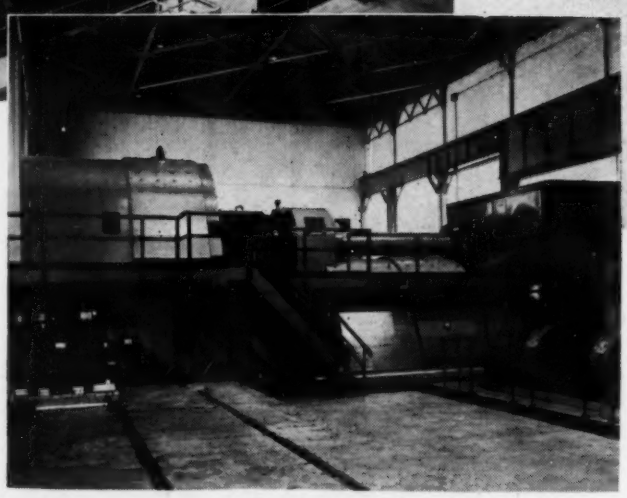


10,000 hp Twin-Motor Single Armature Installation in a *Slab Mill.*





10,000 hp Twin-Motor Double Armature Installation in a *Beam Mill.*



10,000 hp Twin-Motor Single Armature Installation in a *Slab Mill.*

WESTINGHOUSE TWIN-MOTOR DRIVE PROVIDES . . .

- Saving in Roll Wear
- Improved Quality of Steel Product
- Low Inertia
- Extreme Flexibility
- Smooth Operation
- Elimination of Pinion Stands
- Compensation for Roll Diameter Variation
- Compensation for Pitch Diameter Variation between top and bottom rolls — as in tube forming mills

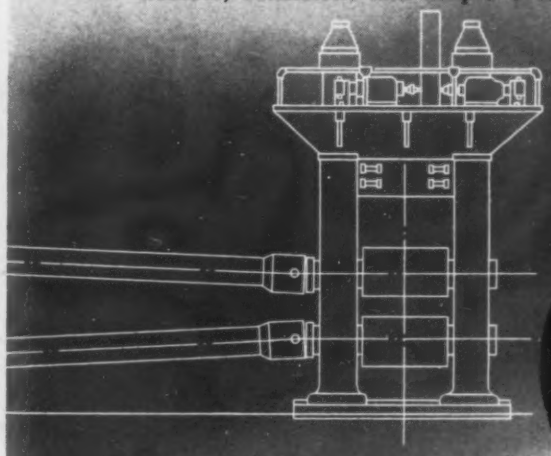
Westinghouse . . . . ELECTRICAL

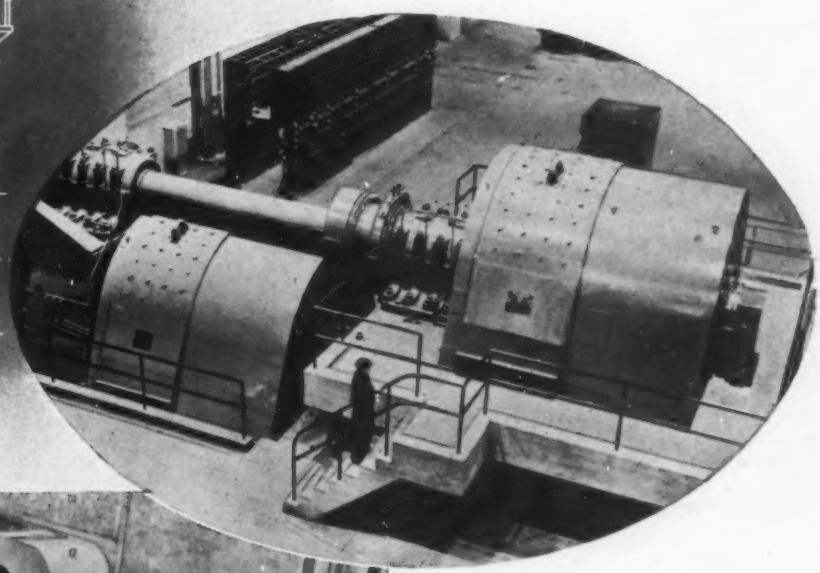
Twin-motor Drives

SPARE THE ROLLS • STEP UP QUALITY

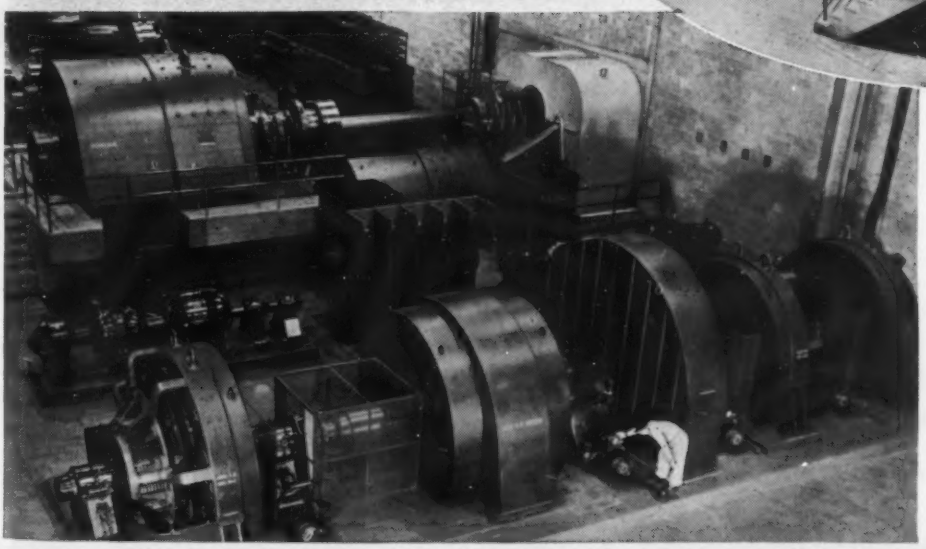
The Twin-Motor Drive, originated by Westinghouse for steel mill duty, is now operating in leading mills on a wide variety of applications. The principle is simple. One motor drives the upper roll; its "twin" drives the lower. Complete co-ordination of the two provides a smooth power flow—flexible, consistent and ample even under heavy overloads. Roll wear is minimized, product uniformity is improved and output is increased.

Consultation of Westinghouse steel mill drive experts is yours for the asking. Call your nearest Westinghouse office or write Westinghouse Electric Corporation, P.O. Box 868, Pittsburgh, Pa. J-94714





10,000 hp Twin-Motor Single Armature Installation in a *Plate Mill.*



10,000 hp Twin-Motor Single Armature Installation in a *Slab Mill.*

OTHER APPLICATIONS OF THE TWIN-MOTOR DRIVE

- Tandem Cold Reduction Mills
- Tension Devices for Skin Pass Mills
- Main Drives . . . Skin Pass Mills
- Forming and Sizing Rolls for Tube Mills
- Plater Roll Drives for Tinning Lines

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MORGAN CONSTRUCTION CO. WORCESTER, MASS.
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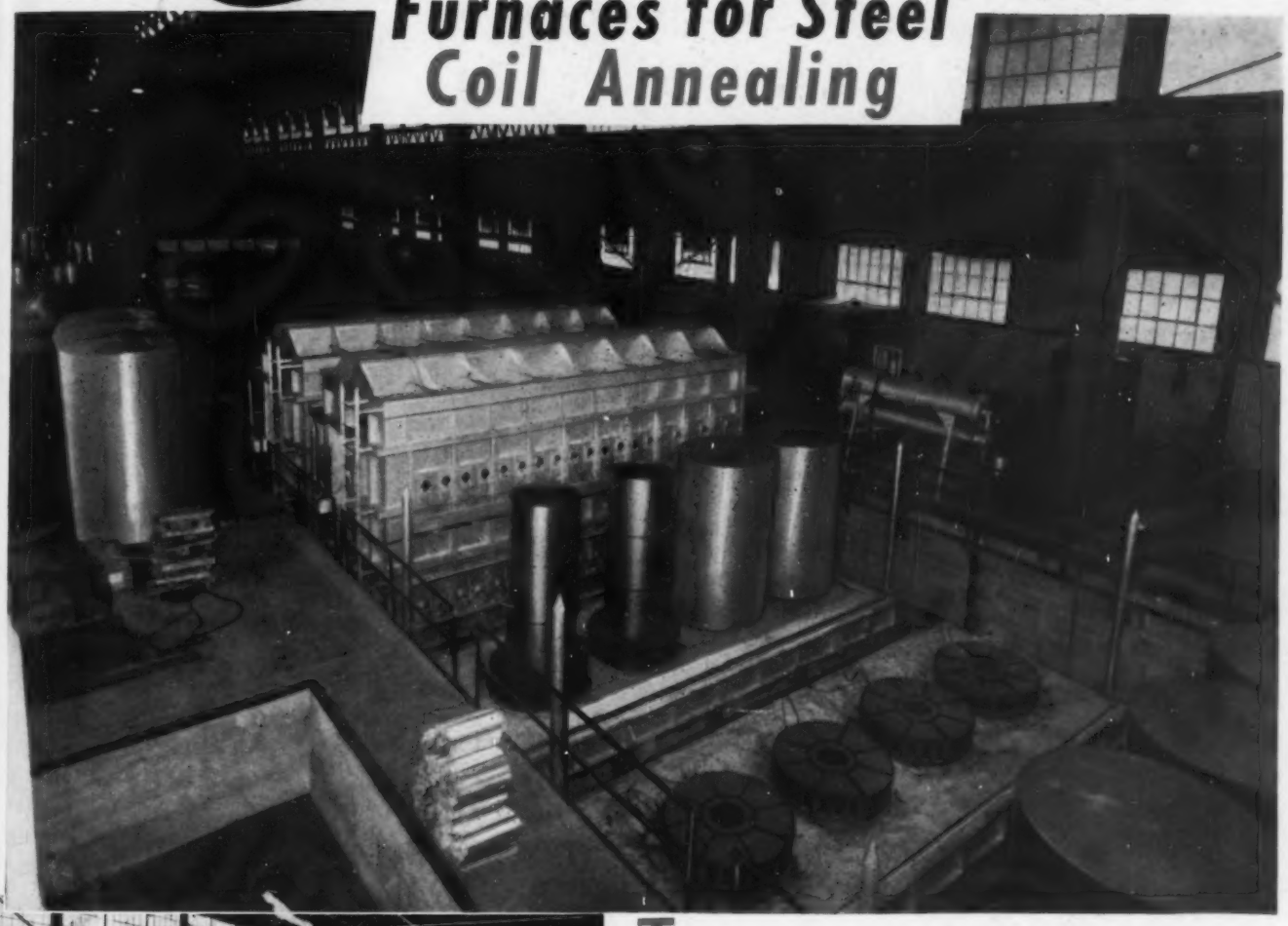
ENGINEERS AND BUILDERS OF ROLLING MILLS
WIRE MILLS • GAS PRODUCER MACHINES
REGENERATIVE FURNACE CONTROL

English Representative: International Construction Co., 56 Kingsway, London, W. C. 2, England

WILSON Rectangular and Cylindrical Bell Type Furnaces for Steel Coil Annealing



THE Lee Wilson Engineering Company is ready for the new expansion in the strip sheet and tin plate industry.

New developments in the use of radiant tube and convection heating will increase the tons per hour yield in annealing furnaces designed for larger coil diameters and increased piling heights.

The Wilson Annealing Unit is covered by Patents Nos. 1,952,402, 2,068,477, 2,078,356, 2,081,612, 2,089,843, and other patents pending.

ENGINEERED AND CONSTRUCTED BY THE

Lee Wilson ENGINEERING Co., Inc.

20005 West Lake Road CLEVELAND, OHIO

Telephone ACademy 4670

Sold by The WEAN ENGINEERING CO., Inc., Warren, Ohio

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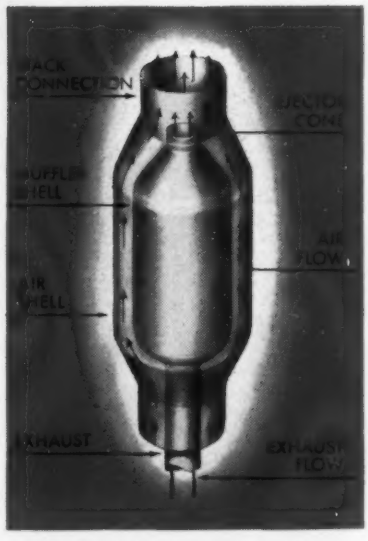
THE MUFFLER THAT KEEPS ITSELF COOL

The FLUOR *Air-Cooled* Muffler cools itself... and the entire exhaust system... by using engine exhaust energy to pull a steady stream of air through its entire length. No insulation of any kind is required. Corrosion in the entire system is minimized because of cooler, drier operations. This coolness means less shutdown time for painting, and longer muffler life.



All FLUOR Air-Cooled Muffler Designs are fully protected by U.S. Patents & Patents Pending.

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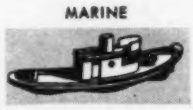
BE SURE SINCE 1890 WITH FLUOR



FLUOR

ENGINEERS • MANUFACTURERS • CONSTRUCTORS

When the Rods are RIGHT...

Your tanks STAY TIGHT!

There's no trick in keeping a new pickling tank tight.

But after the newness wears off, keeping it tight and leakproof depends on the tie-rods.

What's the test of a tie-rod?

Can yours be *repeatedly* drawn up? Do they maintain their holding power, and thus reduce repair and maintenance costs? Do they keep seams tight, and save you the trouble and expense of replacing acid lost through seepage?

You'll answer *yes*... if your tie-rods, nuts and washers are Monel.* For Monel is strong and tough; it provides exceptional resistance to corrosive pickling solutions.

Compare this performance

In tests undertaken by a large steel mill, Monel tie-rods remained smooth (and were only slightly discolored) after 2448 hours in a 5-7% sulfuric acid pickle at 180° F. Under identical conditions, two other commonly used tie-rod metals showed serious deterioration with only a core of original metal remaining.

Load tests after service revealed that the Monel rods had a greater than 3-to-1 strength advantage over both competitive metals. Furthermore, the condition of the threads on Monel rods was better; there was no significant attack *ahead* of the nut. In other words, full usefulness of the rods was preserved. Nuts could be tightened without danger of stripping the threads or snapping the rods.

A valuable report for you

When you order new tanks... or find it necessary to re-rod those you have... you'll want to consider the many advantages of Monel tie-rods. We suggest, therefore, that you send for the informative report, *Summary of an Extensive Tie-Rod Test Program.* Its charts, drawings, tables, photographs and text bring you a lot of factual, helpful material. Write today for your copy. The International Nickel Company, Inc., 67 Wall Street, New York 5, N. Y.

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Monel

The Mackintosh-Abramsen straightener

removes end bends

THE MACKINTOSH-ABRAMSEN STRAIGHTENER speeds up production, cuts operating costs and delivers an absolutely straight product—end to end.

There are no guides to ring or score the stock. The action of the rolls can be controlled to produce the exact quality of surface finish that is required. Elimination of supporting guides, the use of symmetrical passes, and a balanced arrangement of the drives, result in a very considerable power saving—the power consumed per foot of product sized or straightened is usually about fifty per cent of that required by other machine types.

Because Mackintosh-Abramsen straighteners are not closed in, all parts can be easily reached for rapid adjustment and roll changes. This feature results in less "down-time,"—more production.

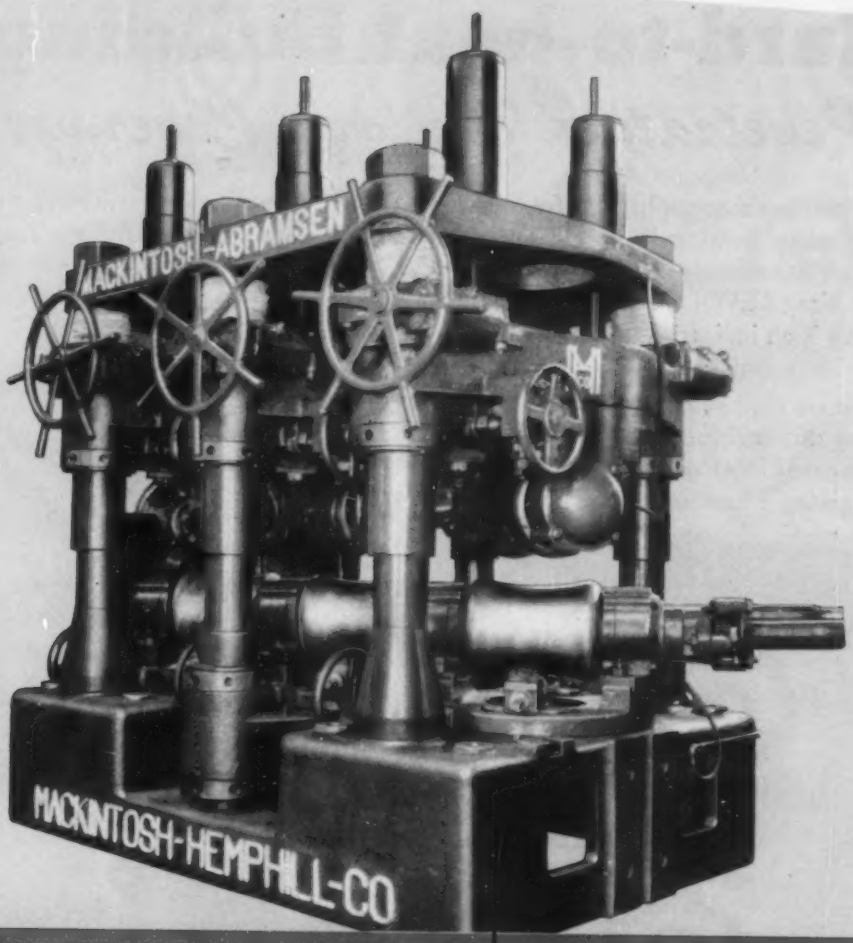
By setting the middle pair of rolls out of line in relation to the other two pairs, an ideal condition for end to end straightening is accomplished thus guaranteeing absolute straightness of stock. The double roll middle pass prevents weaving or sidewise movement of the stock and causes straightening of long bends and end camber to take place in three passes instead of one. The bending action on the stock takes place from the end of the rolls in the first pass to the end of the rolls in the middle pass, and again from the middle pass to the third pass. Thus the bending or straightening action on the stock is from section to section of the stock, and is not dependent on the contour of the rolls.

The symmetrical contour of the rolls forming the three passes and the balanced arrangement of the driven rolls result in a uniform wear on the surface of the roll. The rolls are continuously "wearing in" instead of "wearing out." The machine, therefore, requires fewer roll dressings and, hence, gives greater roll life.

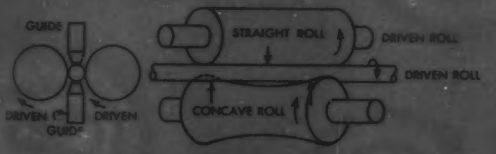
The straightener is available for cold finishing of hot rolled or cold drawn bars up to 9″ diameter, and tubing or pipe in all sizes from ¼″ O.D. to 28″ O.D. On some products, production speed in excess of 500 feet per minute is attained.

MACKINTOSH-HEMPHILL COMPANY, ***Pittsburgh and Midland, Penna.***

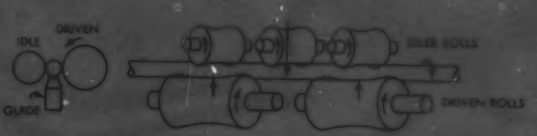
Makers of the Rolls with the Red Wabblers



PRESENT-DAY PRACTICE



Method No. 1: Straightening is done in one set of cross rolls. Guides are used to hold material on the pass line. The straightening takes place from point to point on the rolls and against the guides. Efficiency drops with wear on the rolls.



Method No. 2: Straightening is done by a pressure roll between two cross roll passes—Material is held on the pass line by a bottom guide—The straightening takes place from point to point on the rolls and against the guide. Efficiency drops with wear on the rolls.

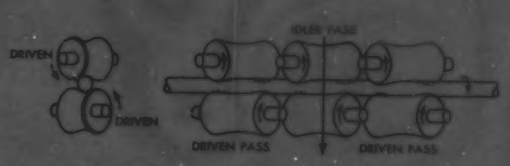
Investigate the possibilities of the Mackintosh-Abramsen Straightener

it will:

1. Give you a straighter product hot or cold
2. Give you a smoother, cleaner product
3. Increase production rates
4. Lower production costs
5. Remove out of roundness

it won't:

1. Spiral mark thin wall tubes or soft material
2. Guide score finished material
3. Unduly harden ductile materials
4. Destroy the surface on coated materials



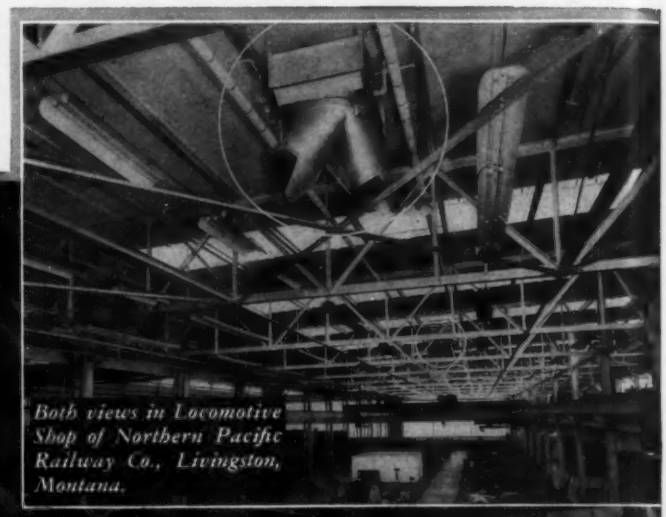
The Mackintosh-Abramsen Method—Straightening is accomplished by an offset cross roll pass between two fixed cross roll passes (patented)—No guides are required because the rolls are driven on both sides of the material which is supported by the bottom rolls. With this balanced arrangement there is no decreasing efficiency from uneven wearing of the rolls. The straightening takes place from section to section and not from point to point.

Wing Revolving Heaters for Hard-to-heat Buildings

Thorough Penetration, Uniform Coverage

The photographs shown on this page exemplify the type of industrial building where heating is a serious problem. Railway shops are notoriously hard to heat and the success with which Wing REVOLVING Unit Heaters have met this problem is an indication of their suitability for all types of industrial buildings regardless of heating difficulties.

Revolving discharge outlets give thorough, uniform coverage, circulating under and around obstructions, into far corners and repair pits, giving a sensation of fresh, live, invigorating warmth to workers. And in Summer, with the steam turned off and the fans on, these same revolving outlets keep the air in constant, gentle motion, bringing relief and comfort on the hottest days.



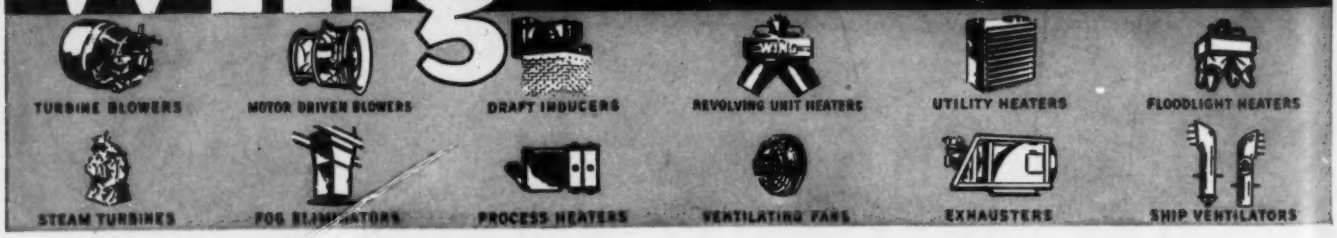
Both views in Locomotive Shop of Northern Pacific Railway Co., Livingston, Montana.

Write for Bulletin: "Wing Revolving Unit Heaters"

L. J. Wing Mfg. Co. 154 W. 14th St., New York 11, N. Y.

Factories in Newark, N. J. and Montreal, Canada

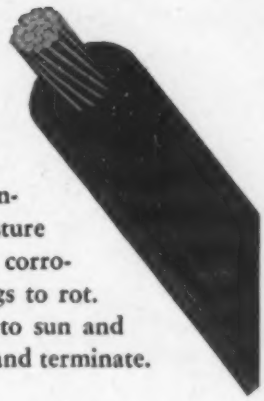
Wing REVOLVING UNIT HEATERS



4 OF MANY CABLES

engineered by OKONITE

OKOLITE-OKOPRENE



Versatile, low in maintenance cost, Okolite-Okoprene* is designed for service up to 5,000 volts, for control wiring, lighting and power circuits. Its Okolite oil-base insulation has excellent electrical properties. Its outer protective jacket of non-flammable Okoprene resists moisture and oil as well as abrasion and corrosion. Contains no fibrous coverings to rot. May be buried in earth, exposed to sun and elements. Simple to handle, splice and terminate.

*Patent No. 2,312,058

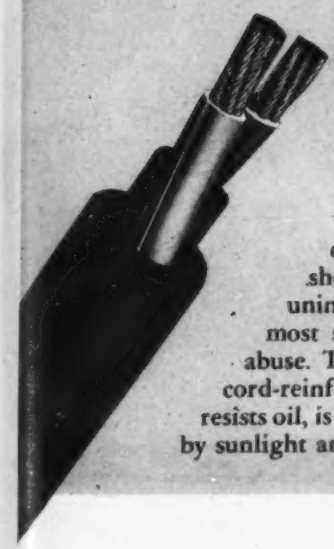
OKOLITE-OKOPRENE *for high voltages*

Okolite-Okoprene high voltage cables are supplied for service up to 35,000 volts a. c.—110,000 volts d. c. with protective shielding as conditions demand. Hundreds of thousands of feet of Okolite-insulated high voltage cables for generator leads, high voltage feeders to motors, transformer leads, submarine cables and other power circuits have proved their efficiency under all kinds of operating conditions.

VARNISHED CAMBRIC

Okonite varnished cambric insulated wires and cables for operations up to 28,000 volts comprise a complete line for all types of power circuits. A wide range of outer protective coverings is available. These outer coverings include fibrous sheaths, lead sheaths, interlocked metallic tape and armor wire, asbestos braid, and flame retardant cotton braid as well as Okoprene and other non-metallic synthetic sheaths.

OKOCORD PORTABLE CABLES



Extra flexible stranding is standard in all Okocord portable cords and cables designed for leads on electrical welding equipment, tools, portable equipment, magnet cranes, dredges and electric shovels. Designed to transmit uninterrupted power under the most severe conditions of external abuse. This cable is furnished with a cord-reinforced Okoprene jacket that resists oil, is non-flammable and unaffected by sunlight and exposure.

Engineers in all branches of industry are invited to bring their problems of electrical transmission and distribution to Okonite engineers. By combining their experiences, the correct selection of wires and cables is made easy, low maintenance and long life assured. The Okonite Company, Passaic, New Jersey.

OKONITE

SINCE 1878

insulated wires and cables

4182

CROUSE-HINDS FLOODLIGHTS

The illustrations show a representative selection from the dozens of different Crouse-Hinds floodlights — each designed for its particular purpose. Crouse-Hinds lighting engineers will recommend the proper selection and arrangement of floodlights for any application. Send drawings and details.

No. 4
of a series of advertisements which demonstrate that CROUSE-HINDS "complete line" means much more than just a range of sizes—there is a wide variety of highly specialized types in each classification.

Type MDB-8
100-Watt

Type MDB-10
200-Watt

Type MDB-14
500-Watt

Type MDB-16
1000-Watt

Type MUA Elliptalux
750 to 1500-Watt

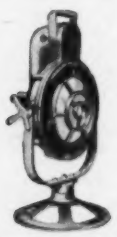
Type MUA Alumalux
750 to 1500-Watt

Type ADE-12
Heavy Duty
200 or 250-Watt

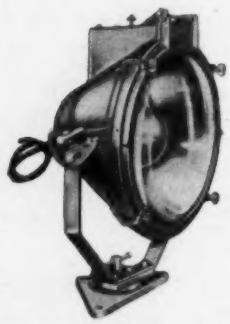
Type ADE-14
Heavy Duty
500-Wall

Type ADE-16
Heavy Duty
1000-Watt

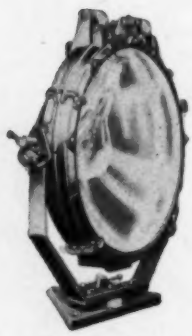
Type ADR-14
Heavy Duty
Portable 500-Watt



Type RCDE-8
Explosion-Proof
Portable
200-Watt



Type LCE-1120
Heavy Duty
1500-Watt



Type LCE-24
Heavy Duty
2000-Watt

Type RCDE-8
Explosion-Proof
200-Watt

Type RMC-8
Wall Mounting
100-Watt

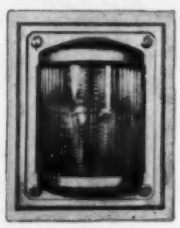
Type RCD-8
Wall Mounting
100 to 200-Watt

Type RCD-8
Floor Mounting
100 to 200-Watt

Type RMF-12
Wall Mounting
150 or 200-Watt

Type FS
Floor Lighting
25-Watt

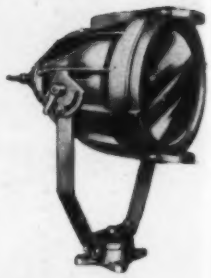
Type VCD-6
Roadway Lighting
60 to 100-Watt



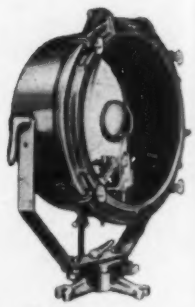
Type VCD-12
Roadway Lighting
200-Watt

Type SPS for
underwater lighting
of swimming pools

Type GCP-14 Lantern
300 to 1500-Watt



Type RLEE-14
Explosion-Proof
500-Watt



Type DCE-18
Long-Range Searchlight

Type DCX-18
Long-Range Searchlight

A Nationwide Distribution Through Electrical Wholesalers

CROUSE-HINDS COMPANY
Syracuse 1, N. Y., U.S.A.

Offices: Birmingham — Boston — Buffalo — Chicago — Cincinnati — Cleveland — Dallas — Denver — Detroit — Houston — Kansas City — Los Angeles — Milwaukee — Minneapolis New York — Philadelphia — Pittsburgh — San Francisco — Seattle — St. Louis — Washington. *Resident Product Engineers:* Albany — Atlanta — Charlotte
CROUSE-HINDS COMPANY OF CANADA, LTD., *Main Office and Plant:* TORONTO, ONT.

CONDULETS · TRAFFIC SIGNALS · AIRPORT LIGHTING · FLOODLIGHTS

"..... ALL IS BRIGHT"

May Peace, Joy and Happiness be yours at Christmastime and throughout the coming year.

United Engineering and Foundry Company

PITTSBURGH, PENNSYLVANIA

IS IT SHARP... ABRASIVE... HOT... *Tough-to-Handle?*

...Then move it with a LINK-BELT "*Oscillating-Trough*" CONVEYOR!

● Materials that prove "too much" for belt or apron conveyors are being handled easily, at low cost and with far less maintenance, with LINK-BELT'S New Oscillating-Trough Conveyor.

Several years service, handling hot sand, castings, steel scrap from shears, rolling mill scale, borings, wet and abrasive materials fully demonstrates the outstanding advantages of this conveyor, in foundries, machine shops or wherever material handling is a really tough problem.

Flexible in the extreme, the O-T Conveyor can be built to a wide range of capacities, can be installed to any length, and with longitudinal partitions will carry more than one material without mixing or spilling. Metal working plants, mills, and smelters have needed the O-T Conveyor. Here it is, service-tested, proved, and backed by the builders of the most complete line of conveying and materials handling machinery.

New...

PROVED IN SERVICE

Long-hanger type oscillating-trough conveyor, carrying hot sand and castings from shakeout.

10,118

Short-hanger type, oscillating-trough conveyor, adaptable to installing in a shallow trench, for conveying turnings, borings, etc.

LINK-BELT

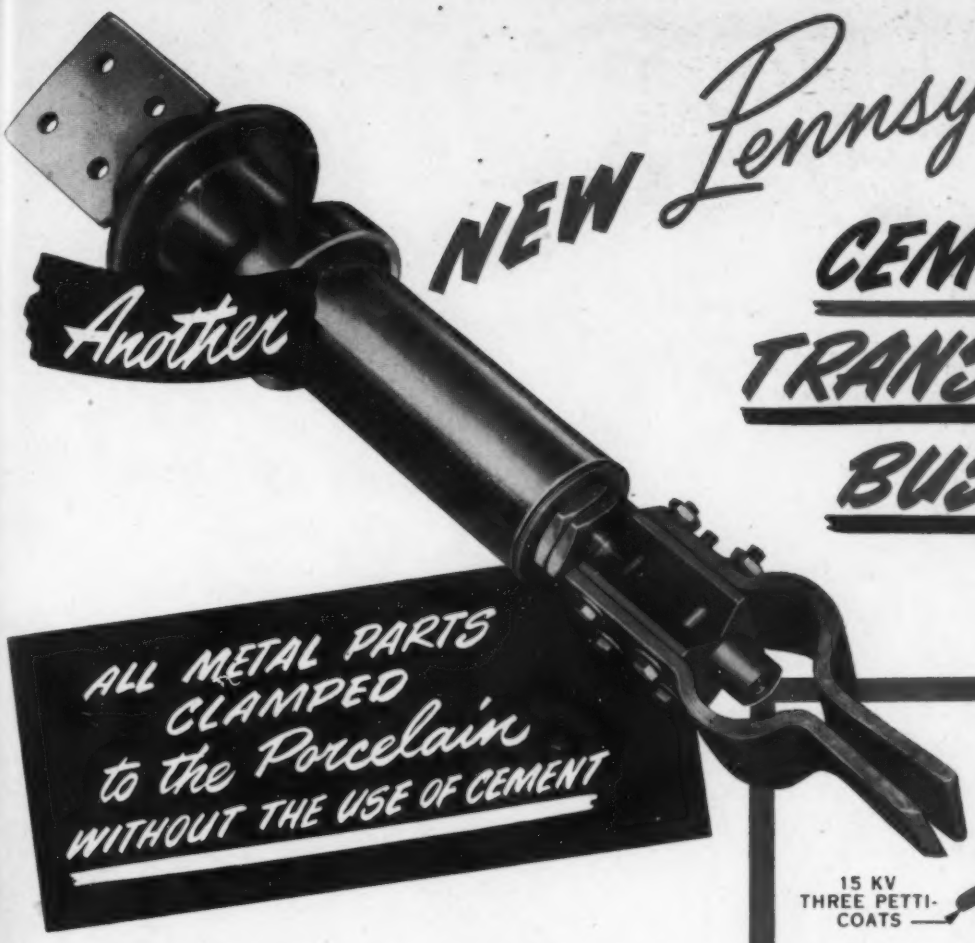
OSCILLATING-TROUGH CONVEYOR

Send for Folder No. 2088

LINK-BELT COMPANY

Chicago 9, Indianapolis 6, Philadelphia 40, Atlanta, Dallas 1, Minneapolis 5, San Francisco 24, Los Angeles 33, Seattle 4, Toronto 8. Offices in Principal Cities.

Another NEW Pennsylvania CEMENTLESS TRANSFORMER BUSHING

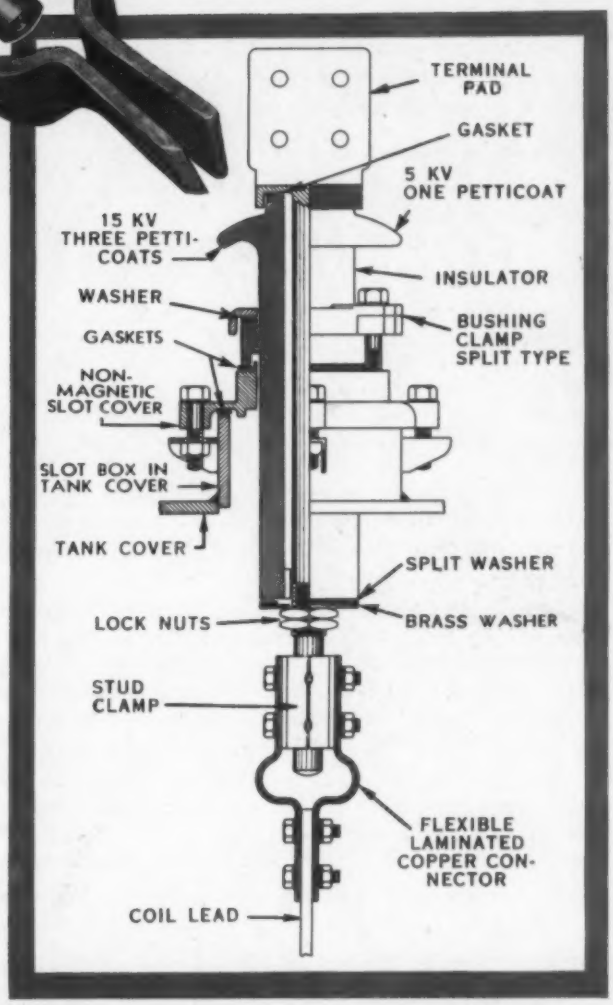


High Current Rating 500 to 3,000 Amperes
Voltage Ratings—5,000 and 15,000 Volts

This is a dry-type bushing made of wet process porcelain. *All joints between the porcelain and metal parts are sealed by clamping without the use of cement.* This method of union applies to the terminal stud as well as to the flanges and provides an oil-tight joint between the porcelain and the transformer cover. The *elimination of cement* facilitates replacement of the insulator and *assures oil-tight and gas-tight joints.*

On the lower end of the bushing conductor, a laminated connector is attached to the transformer lead. Being flexible, this connector eliminates the transmission of stresses from the coil lead to the porcelain insulator. The absence of such stresses assures tightness of the joints between the porcelain and metal parts. Heavy alloy bolts are used throughout for electrical and mechanical connections.

Unnecessary losses and heating are eliminated by mounting the bushing in a non-magnetic slot cover. Non-magnetic metal clamps are used for attaching the bushing to the cover. These clamps, being of the split type, permit easy installation or removal of the complete insulator including the hardware.



Pennsylvania TRANSFORMER COMPANY
808 Ridge Avenue, N. S., Pittsburgh 12, Pa.

Pennsylvania TRANSFORMERS

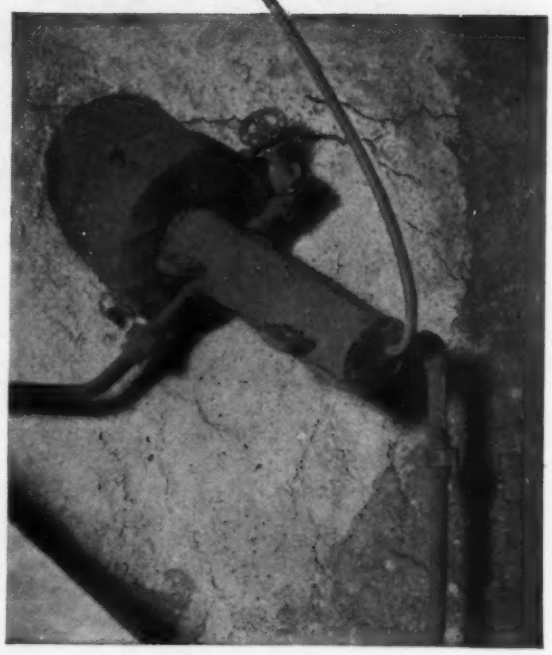
RAYOTUBES IN CHECKERS SAVE MONEY FOR INLAND STEEL

Inland's Indiana Harbor plant reduces maintenance costs by replacing the thermocouples in the checker chambers of their 36 open-hearth furnaces with Rayotubes. Where the thermocouples demanded considerable attention and burned out frequently, Rayotubes require little maintenance other than an occasional cleaning and checking. Once a Rayotube is installed, it's there to stay; it holds its calibration, and it *does not burn out.* Instead of going *to* the heat, as thermocouples do, Rayotubes stay in a safe location and receive radiation *from* the hot surface on which they are sighting.

And Rayotubes are giving Inland much better recorder readings than thermocouples formerly gave. This is partly due to the extreme sensitivity of Rayotubes; since they are sighted directly on the roof of the neck arch, with no protection tubes, they have no lagging and consequently detect every change in temperature the instant it occurs.

Another and equally important reason for the success of Rayotubes in this plant is that they measure temperature at a location which is too hot for couples. By thus working nearer the maximum, they assist the First Helper in avoiding refractory damage.

Our engineers will be glad to make specific recommendations for use of Rayotubes, or they will send Catalog N-33B, as you prefer.



This Rayotube at Inland Steel Co., Chicago, is mounted in the checker chamber wall of an open-hearth furnace. It receives radiation and reports temperatures to the Micromax Recorder (see arrow) by means of the lead-wire, just as a thermocouple would do.

LEEDS & NORTHRUP COMPANY, 4942 STENTON AVE., PHILA., PA.

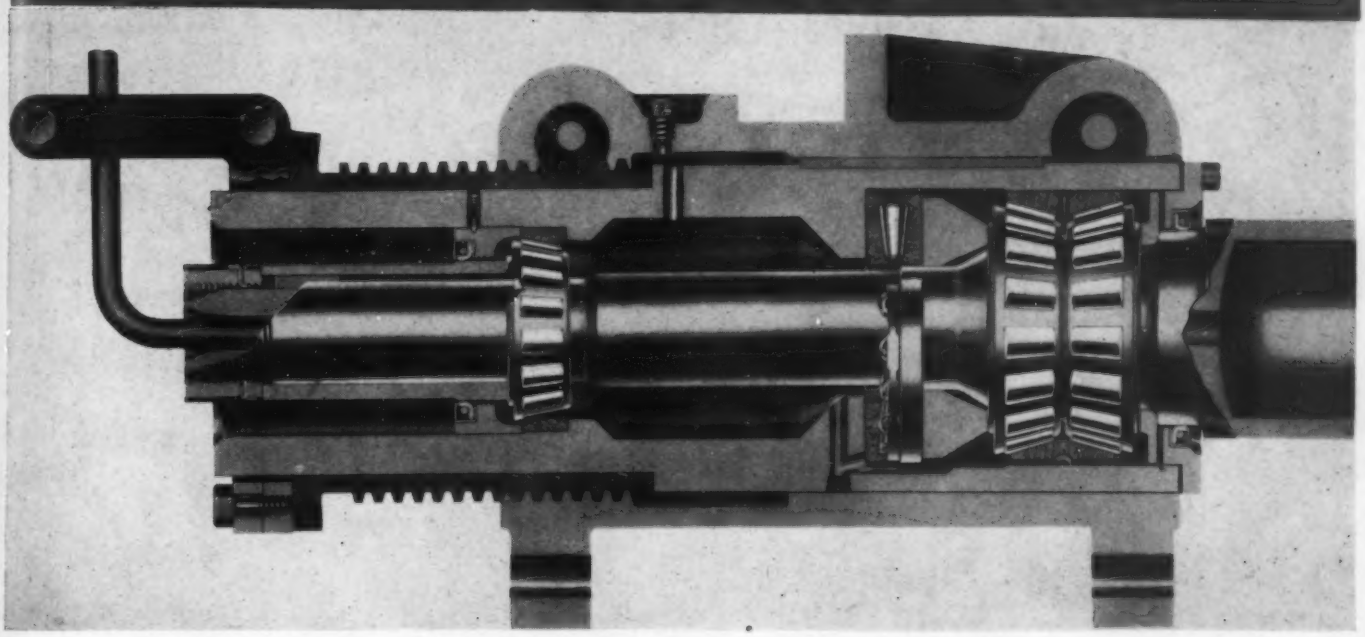
LEEDS & NORTHRUP

MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES

Jrl Ad N-33B(6)

From Zero to Mandrel Speed

IN NOTHING FLAT!



Well, the operation of Timken Bearing Equipped piercing mill thrust blocks is almost that fast; no sluggishness as with plain bearing blocks. Zooming from zero to 1200 RPM for example is a matter of split seconds.

Timken Bearing Equipped thrust blocks keep going indefinitely without maintenance because friction and wear are eliminated; radial, thrust and combined loads are kept under complete control; lubrication is simplified; and thrust block rigidity greatly increased.

For specific information covering the application of Timken Bearing Equipped thrust blocks in your mills consult the mill builder or our engineers.

THE TIMKEN ROLLER BEARING COMPANY, CANTON 6, OHIO

TIMKEN

THE TRADE-MARK REG. U. S. PAT. OFF.

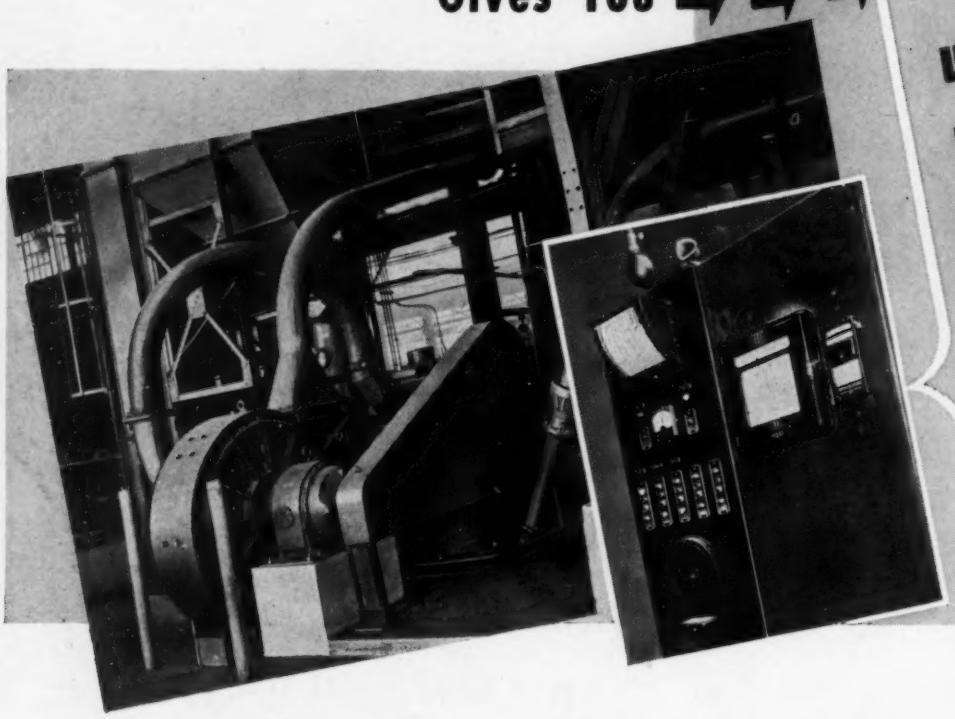
TAPERED ROLLER BEARINGS

B&W Direct-Firing Pulverized-Coal System for Metallurgical Furnaces Gives You

ONE-POINT FUEL CONTROL

UNIFORM FURNACE TEMPERATURE

ECONOMICAL OPERATION



Close regulation of coal-air ratio and volume —an important feature in the operation of most metal-heating furnaces—is *automatically* obtained with the B&W Direct-Firing Pulverized-Coal Circulating System by controlling the rate of coal feed to the pulverizer so that it is proportional to the primary-air flow.

Once the controller is adjusted for a specific heat, both coal and primary air are always properly proportioned for most efficient combustion and with minimum attention of the operator, the pulverizer supplies coal of proper fineness to the circulating loop at the same rate it is being used by the burners at any particular moment. A substantially constant density of coal and air is assured in the circulating line at all times.

This automatic control provides the same flexibility of multi-furnace operation as with gas or oil—burners may be turned on or off, and adjusted as desired.

Simple, dependable, and convenient, this one-point automatic control is but one of several cost-saving features that make B&W pulverizers so economical for direct-firing of metallurgical furnaces—with and without a circulating system—where high output of high-grade metal products is of prime importance.

Write for *"Pulverized-Coal Firing of Metallurgical Furnaces,"* a 14-page booklet discussing this subject in detail.

B&W

Water-Tube Boilers, for Stationary Power Plants, for Marine Service . . . Water-Cooled Furnaces . . . Superheaters . . . Economizers . . . Air Heaters . . . Pulverized-Coal Equipment . . . Chain-Grate Stokers . . . Oil, Gas and Multifuel Burners . . . Seamless and Welded Tubes and Pipe . . . Refractories . . . Process Equipment.

BABCOCK & WILCOX

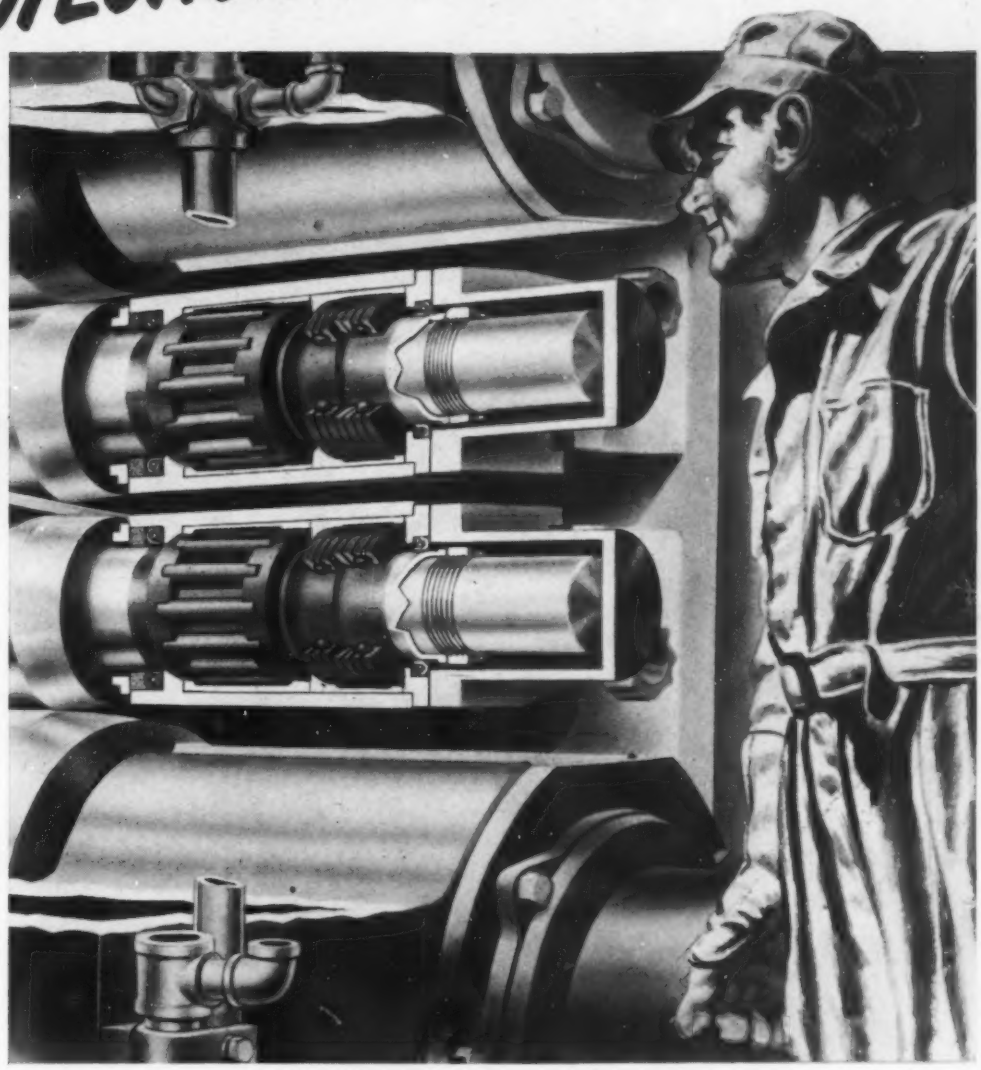
THE BABCOCK & WILCOX CO.

85 LIBERTY STREET, NEW YORK 6, N.Y.

PM-109

Give Your Work-Roll Bearings This

NEW PROTECTION AGAINST HEAT, WATER, SHOCKS



Gargoyle Grease Sovarex L, Is Specially Designed for Heavy-Duty Steel Mill Service

You don't have to stretch your imagination to appreciate the job that grease has to do here on these work-roll bearings. You know that it is subjected to terrific heat, water and shock loads.

Yet despite all these forces, the grease you select must stand up at high temperature, protect the bearings from wear, *keep work rolls working.*

Socony-Vacuum's new patented grease—Gargoyle Grease Sovarex L—is specially designed to meet tough steel mill conditions like this—on work-roll, back-up-roll, and table-roll bearings. It is in service under temperatures as high as 450° F. It resists the washing action of water and is standing up under the heaviest pressures encountered.

Mill operators already are using this new grease in no less than 56 different spots in their plants and are reporting highly satisfactory results. Get facts and figures from your Socony-Vacuum Representative.

SOCONY-VACUUM OIL CO., INC.
Standard Oil of N. Y. Div. • White Star Div. • Lubrite Div. • Chicago Div. • White Eagle Div. • Wadhams Div. • Magnolia Petroleum Company • General Petroleum Corporation of California.

SOCONY-VACUUM'S 5 Steps to Lower Production Costs:

1. Lubrication Study of Your Entire Plant
2. Lubrication Schedules and Controls
3. Lubricant Storage and Handling System
4. Skilled Engineering Counsel
5. Progress Reports of Benefits Secured

GARGOYLE Lubricants

Tune in "Information Please"—Monday Evenings, 9:30 E.S.T.—NBC

8th ADVANTAGE...

NOT WET BY MOLTEN METAL!

IMAGINE!—1500 steel ingots on graphite stool inserts in one plant—*without any stickers!* That's because molten metals simply do not stick to carbon or graphite!

This eighth advantage of "National" carbon or graphite is only one of many responsible for the adoption of these materials by the metal-working industries, in the form of stool inserts, mold plugs, molds, mold wash (graphite powder), run-out troughs, and furnace linings. Another advantageous feature in run-out troughs and furnace linings: the carbon blocks are unaffected by the most corrosive slags.*

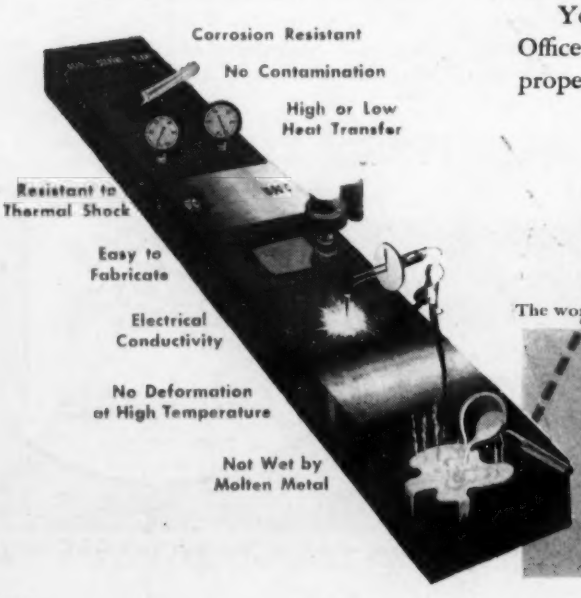
You are invited to get the full story . . . from our nearest Division Office . . . on carbon's, or graphite's, truly remarkable *combination* of properties, whether in the ordinary, porous, or impervious forms.

***Chemical Engineers Please Note**

Of parallel importance to the chemical industries are other advantages of "National" carbon and graphite and "Karbate" impervious materials. They are resistant to the corrosive action of most acids, alkalies, and solvents, and they do not contaminate solutions.

BAR OF WHAT?

Carbon, Graphite, or "Karbate" materials, of course!



The words "National" and "Karbate" are registered trade-marks of National Carbon Company, Inc.

NATIONAL CARBON COMPANY, INC.

Unit of Union Carbide and Carbon Corporation

UCC

General Offices: 30 East 42nd Street, New York 17, N. Y.

Division Sales Offices: Atlanta, Chicago, Dallas, Kansas City, New York, Pittsburgh, San Francisco

BLAST FURNACES

1. BLOWER CONTROL
   - (a) Volume basis
   - (b) Constant weight basis
2. GAS BLEED CONTROL
3. BLAST FURNACE STOVE CONTROL
   - (a) Gas input
   - (b) Gas-air ratio
   - (c) Stove dome temperature

COKE OVENS

1. EXHAUSTER CONTROLS
2. COLLECTING MAIN PRESSURE REGULATORS
3. STACK DRAFT CONTROL
4. UNDERFIRING GAS PRESSURE REGULATORS

BESSEMER

1. AIR FLOW OR AIR PRESSURE CONTROL

OPEN HEARTH

1. HEAT INPUT CONTROL
2. ROOF TEMPERATURE CONTROL
3. FURNACE PRESSURE CONTROL
4. FUEL-AIR RATIO CONTROL
   - (a) Oil firing
   - (b) Gas firing
5. REVERSAL CONTROL

Controls by

HAGAN

everywhere in the

STEEL INDUSTRY

SOAKING PITS

1. TEMPERATURE CONTROL
2. FUEL-AIR RATIO CONTROL
   - (a) Oil firing
   - (b) Gas firing
3. FURNACE PRESSURE CONTROL
4. GAS PRESSURE CONTROL

HEATING FURNACES

1. HEAT INPUT CONTROL
2. FUEL-AIR RATIO CONTROL
   - (a) Oil firing
   - (b) Gas firing
3. FURNACE PRESSURE CONTROL
4. GAS PRESSURE CONTROL

BOILER HOUSES

1. STEAM PRESSURE REGULATION
2. LOAD DISTRIBUTION CONTROL
3. FUEL-AIR RATIO CONTROL
4. FURNACE DRAFT REGULATION
5. AUTOMATIC FUEL MAKE-UP CONTROL

GAS DISTRIBUTION SYSTEMS

1. GAS PRESSURE REGULATIONS
2. MIXING STATIONS
3. SEQUENTIAL DISTRIBUTION CONTROL
4. PRESSURE STABILIZATION CONTROL
5. BLEED CONTROL

HAGAN CORPORATION

Hagan Building • Pittsburgh 30, Pa.

HAGAN HALL BUROMIN CALGON

HAGAN *Automatic* COMBUSTION CONTROL

The pioneer . . . and still the leader

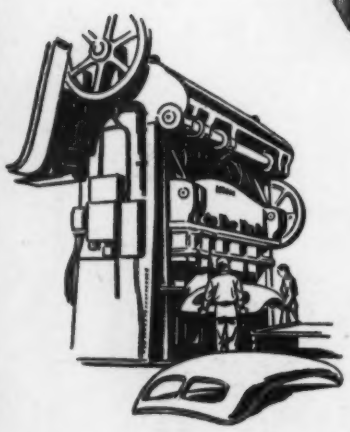
ROLLING TECHNIQUE . . .

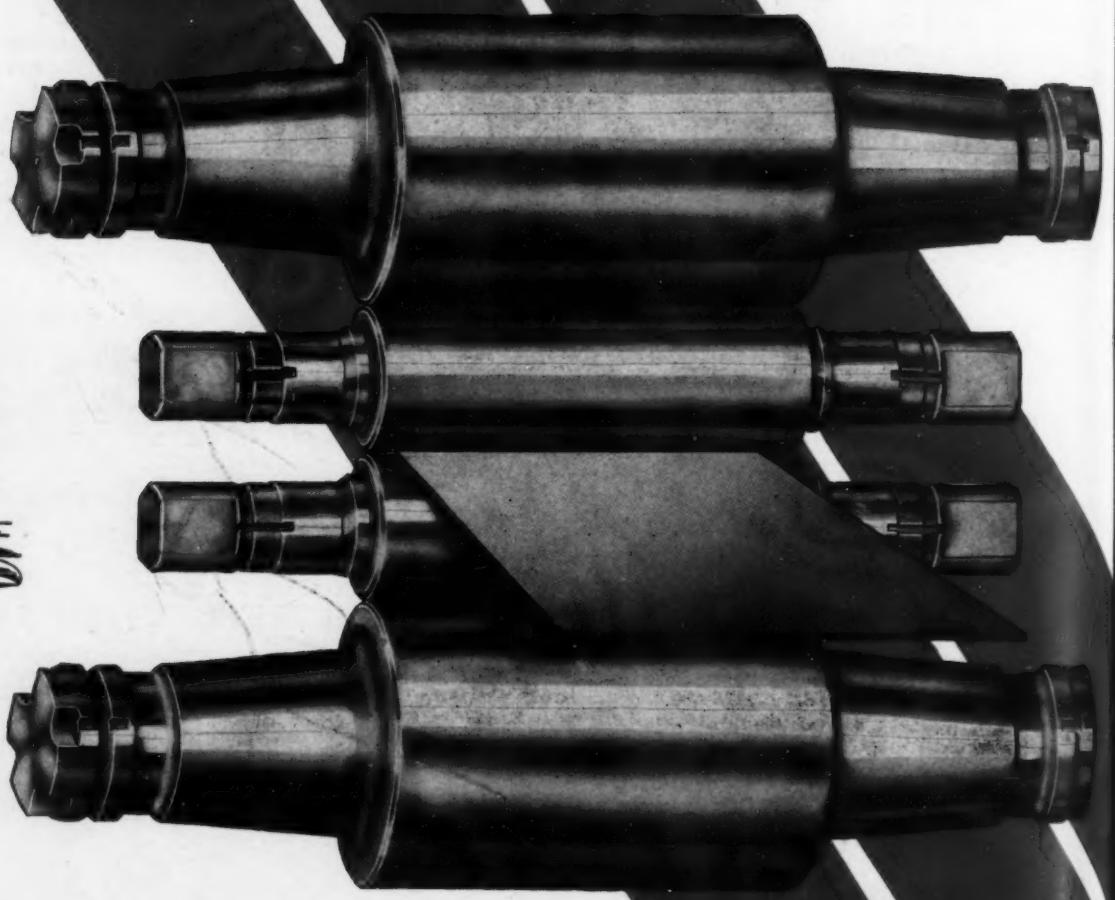
Strip Mills

With reconversion will come the ma peace-time production line products whi will require thousands of tons of coil strip to be stamped and formed into t various parts that make up automobile trucks, airplanes and numerous hous hold appliances.

Pittsburgh Rolls alloy iron *work rolls* a alloy steel *back up rolls* in four-high str mills are rolling aluminum, brass, copp and magnesium, as well as steel, and a successfully producing flat rolled produc *at less cost per ton of steel rolled.*

PITTSBURGH ROLL
DIVISION OF BLAW-KNOX COMPA
Pittsburgh, Pa.





PITTSBURGH ROLLS

"Saves us $7000 a year," says Regulex Control User

An example of savings that scores of furnace operators have discovered with most popular electrode control in industry today.

ACCORDING to figures compiled by one steel foundry, Regulex control on an 11-foot shell arc furnace saved $7000 over a year's period, in power and time savings alone.

Following the introduction of Regulex control for arc furnaces, its cost-saving performance quickly won the confidence of electric melters. *Within the past three years, the Regulex set has outsold every other type of electrode control.*

System is Simple

Regulex control consists of a simple, continuously-connected system of generators and motors. Regulex generators, one for each electrode motor, are driven on a common shaft from a standard induction motor. They instantly make a correction for any power unbalance, no matter how small or how large.

The Regulex generator is a sturdy, standard commutator machine, with no tricky brush adjustments. *The only moving part in the control scheme is the generator armature.* Since contactors and relays are not used, maintenance is slashed!

Exclusive Advantages

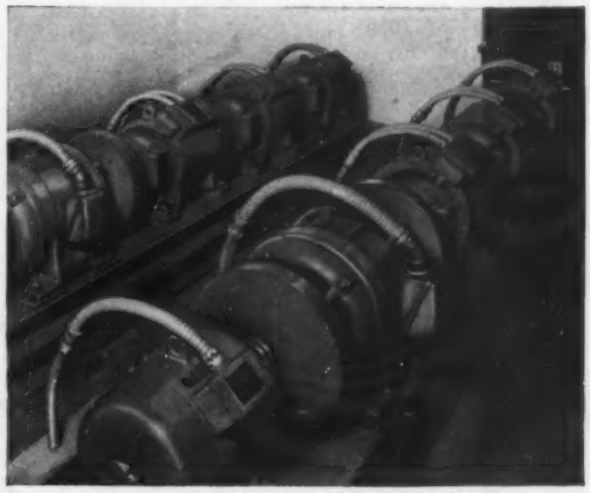
As a unique feature, the Regulex control set can be equipped with flywheels, which *automatically raise the electrodes,* when power fails. The auxiliary generator can make the entire control *independent of a d-c shop source,* when desired.

A Paying Investment

By accurately controlling electrode position during all the changing conditions of the furnace charge, Regulex control lowers kilowatthour cost per ton of steel. Melt-down time is shortened . . . furnace output is boosted. Many users have found that Regulex control pays for itself within a few months!

Your arc furnace manufacturer will be glad to tell you about Regulex control for new or existing furnaces. Or write directly to ALLIS-CHALMERS, MILWAUKEE 1, WISCONSIN.

Furnace controlled by Regulex generators



Regulex control flywheel sets

ALLIS-CHALMERS · MILWAUKEE

A 1888

Rolling Alignment

FOR CONTINUOUS SERVICE

Steel mill men can't afford to take chances on bearings for Ladle Cars. To insure *uninterrupted operation*, they use SKF Spherical Roller Bearings on the journals. Their reason is obvious. The *rolling alignment* of SKF Bearings compensates for axle deflections, distortions or weave . . . insures maximum load carrying capacity at all times. Our engineers will be glad to help *you* with your bearing specifications. 5930

SKF INDUSTRIES, INC., PHILA. 34, PA.

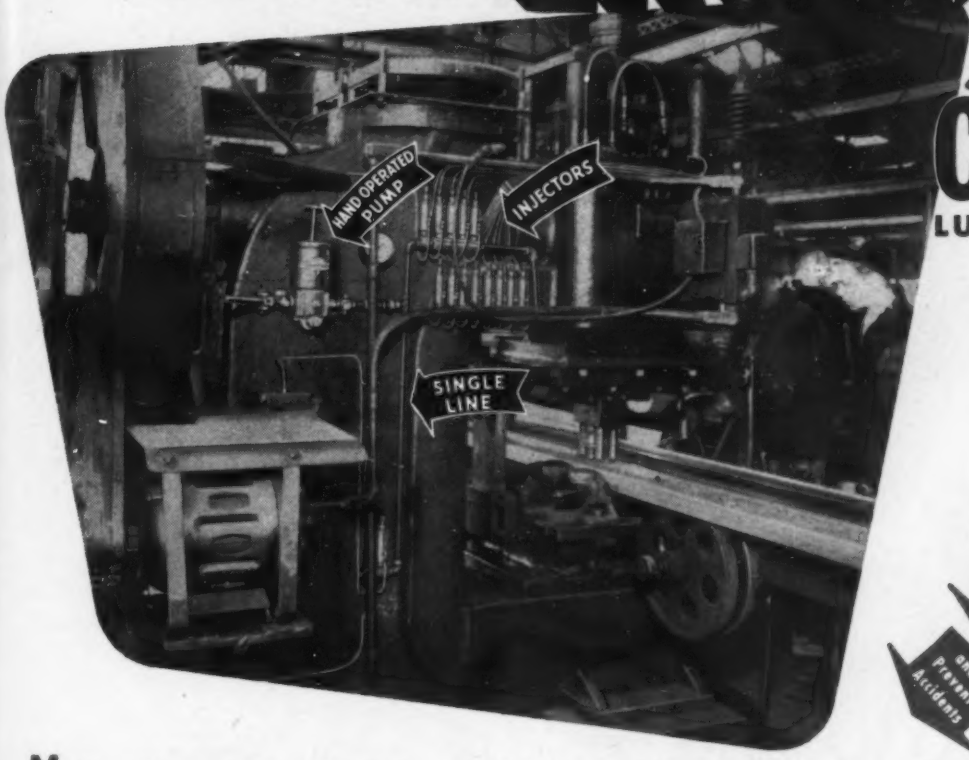
SKF

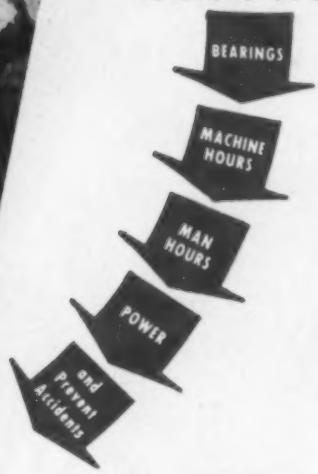
ROLLER BEARINGS

● *Self-propelled 20-Ton Gantry Type Ladle Car built by PENNSYLVANIA ENGINEERING WORKS for Ford Motor Co.*

"Down Time" is Lost Time!..

Install LINCOLN Single Line CENTRO-MATIC LUBRICATING SYSTEMS and save





Machine "down time" results in increased production costs—Today's accelerated production has brought out the inadequacies of older, time consuming methods of lubrication—has proved the importance of Centro-Matic centralized lubricating systems for reducing "down time"—saving power—preventing accidents.

Lincoln Centro-Matic Systems help keep machines on the job — and have shown their dependability in many war-time operations of importance—These systems have inherent features of design that are the answer to many troublesome lubrication problems — check the advantages listed below:

1—Dispense either oil or grease.

2—Deliver a pre-determined measured quantity of lubricant to each bearing.

3—Lubricant delivered at a uniform pressure even to remote bearings.

4—Injectors are easily adjusted for the desired output—no special tools needed.

5—Each injector has external indicator.

6—Complete range of lubricant pumps ——pneumatically, electrically or manually operated.

7—Will pump lubricant from original container at fixed time intervals.

8—All pumping units are of proven design.

9—One pump can supply one machine or a battery of machines.

10—Easy to install. Only one supply line needed.

11—Injectors in manifold can be removed singly without disturbing other injectors.

12—Linpak packing —no metal-to-metal seals.

13—A product of a company that manufactures lubricating equipment exclusively.

Check these facts — compare them with other systems and you will understand why Lincoln Centro-Matic Systems are being used in all types of industrial applications.

Engineering Service

Lincoln Engineering Company maintains a staff of experienced lubrication engineers prepared to assist you in all lubrication problems. Write us, enclosing a blueprint or specifications of the machine you wish to lubricate and we will make a recommendation as to the type of Centro-Matic System best suited to do the job.

LINCOLN

Pioneer Builders of Engineered Lubricating Equipment

MAIL COUPON TODAY

Lincoln Engineering Company, St. Louis 20, Mo.

Please send me illustrated literature on Lincoln Centro-Matic Systems.

*Name*_____

*Title*_____

*Company*_____

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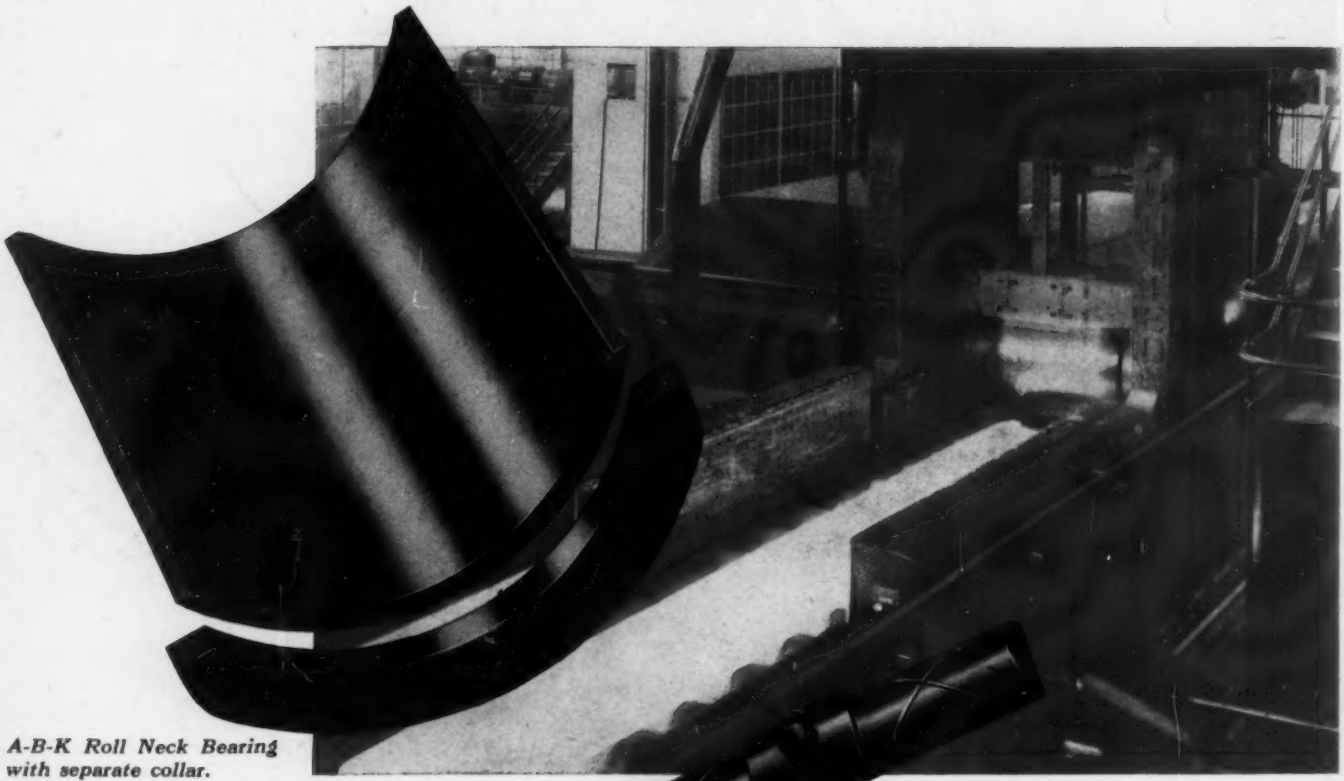
*City*_____ *State*_____

ISE B2524

Speed Up Production – Cut Power Consumption

A-B-K

Laminated Plastic Bearings



A-B-K Roll Neck Bearing with separate collar.

A-B-K Patented Reinforced Edge Slipper Bearing made in required sizes to blue prints.

Phantom view of A-B-K Patented Reinforced Edge Slipper Bearing.

PERFORMANCE check-ups on the operation of A-B-K Laminated Plastic Bearings under peak production in steel mills prove conclusively that—

1 More tons of steel are rolled per set of A-B-K roll neck bearings because the rolls do not need adjusting so often, sheets are rolled to closer gage and the bearings last many times longer than metal.

2 Power consumption shows a substantial dividend on kilowatt hours saved.

3 Many costly shut down periods for bearing replacement are avoided.

4 Roll Neck lubrication costs are practically eliminated.

A-B-K Laminated Plastic Bearings were designed by American Brakeblok engineers to fit the difficult problems of steel mill production.

The same research and engineering facilities that provide these dependable bearings are available to you. Phone, write or wire, American Brakeblok Division, 4600 Merritt Avenue, Detroit 9, Michigan.

American Brakeblok

DIVISION OF AMERICAN Brake Shoe COMPANY

Not just because we're the oldest and largest maker of solid tool steel knives—not because our knives have set such remarkable performance records in other plants—BUT because we *know* that our knives, in your mill, under your own operating conditions will give you more and cleaner cuts per dollar of cost . . . we recommend Heppenstall knives as a basic and proved advantage in meeting tougher marketing competition. Write for a quotation. Heppenstall Co., Pittsburgh 1, Pa.

Heppenstall

the most dependable name in forgings

POOLE

COPY OF CATALOG GIVING FULL DESCRIPTION AND ENGINEERING DATA SENT UPON REQUEST.

FLEXIBLE COUPLINGS

OLE FOUNDRY & MACHINE COMPANY WOODBERRY, BALTIMORE, MD.

Something Special in Maintenance

SALEM CIRCULAR SOAKING PITS

MANY operating men prefer the Salem Circular Soaking Pit for this single reason — trouble-free, minimum cost maintenance.

They know that when relining time comes along, approximately every 4½ to 5 years, they will not have any expensive checkerwork to replace. They know the unique construction . . . straight line wall, small amount of brick used plus the unique cover, help reduce maintenance costs materially.

One company with a multiple Salem Circular Pit installation reports "less than ½ cent maintenance cost per ton of steel heated". . . that's really putting costs in their place.

Minimum maintenance cost is only one of many features. Get the complete quality and cost story from Salem Engineering Company, exclusive builders of Circular Soaking Pits and originators of "Engineered Heat."

Salem builds Circular Pits in any diameters between 8′ and 20′ utilizing any conventional fuel.

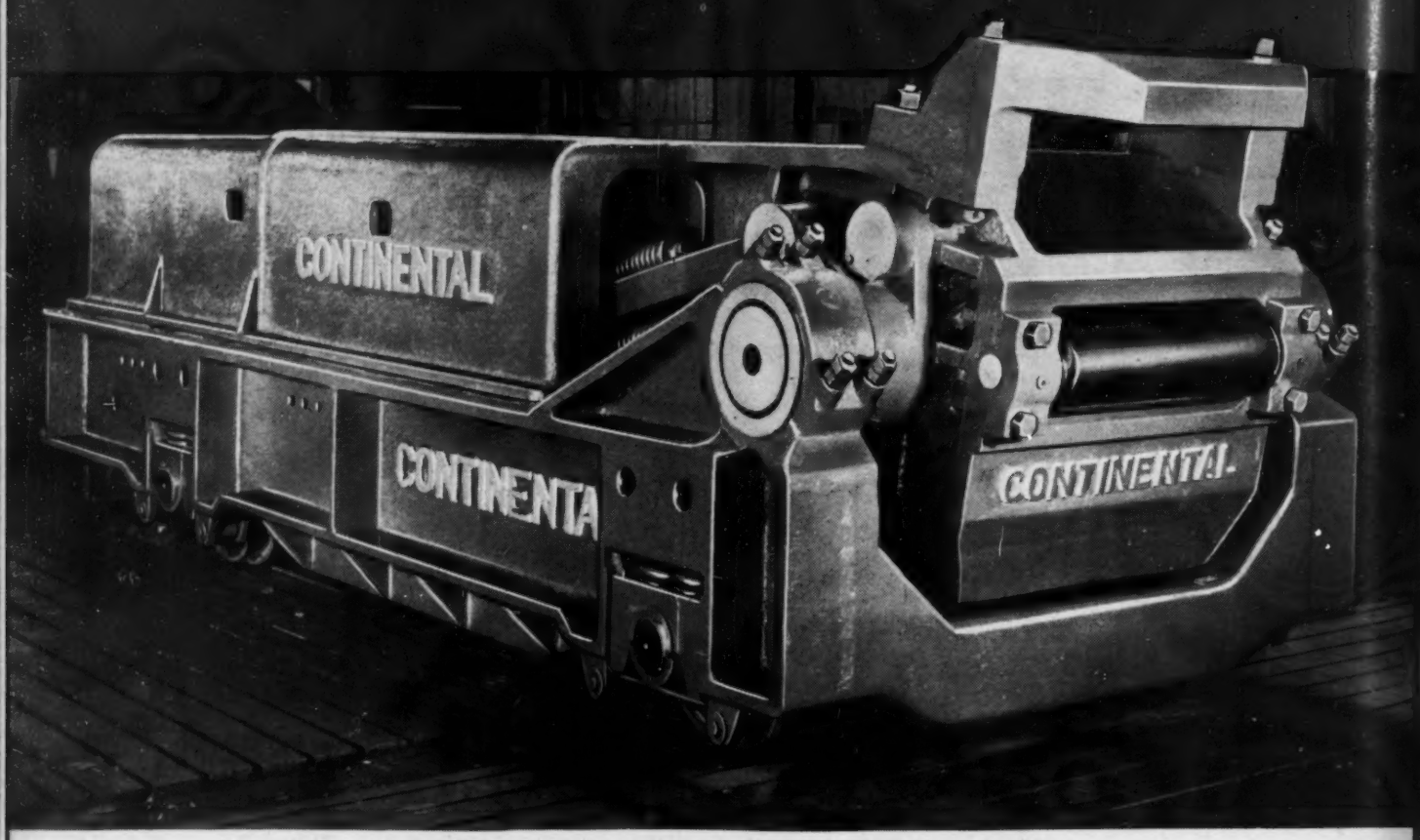
Salem specializes in Engineered Heat for Circular Soaking Pits, and all sizes and types of Heating Furnaces. SEND YOUR HEATING INQUIRY TO SALEM.

SALEM ENGINEERING COMPANY

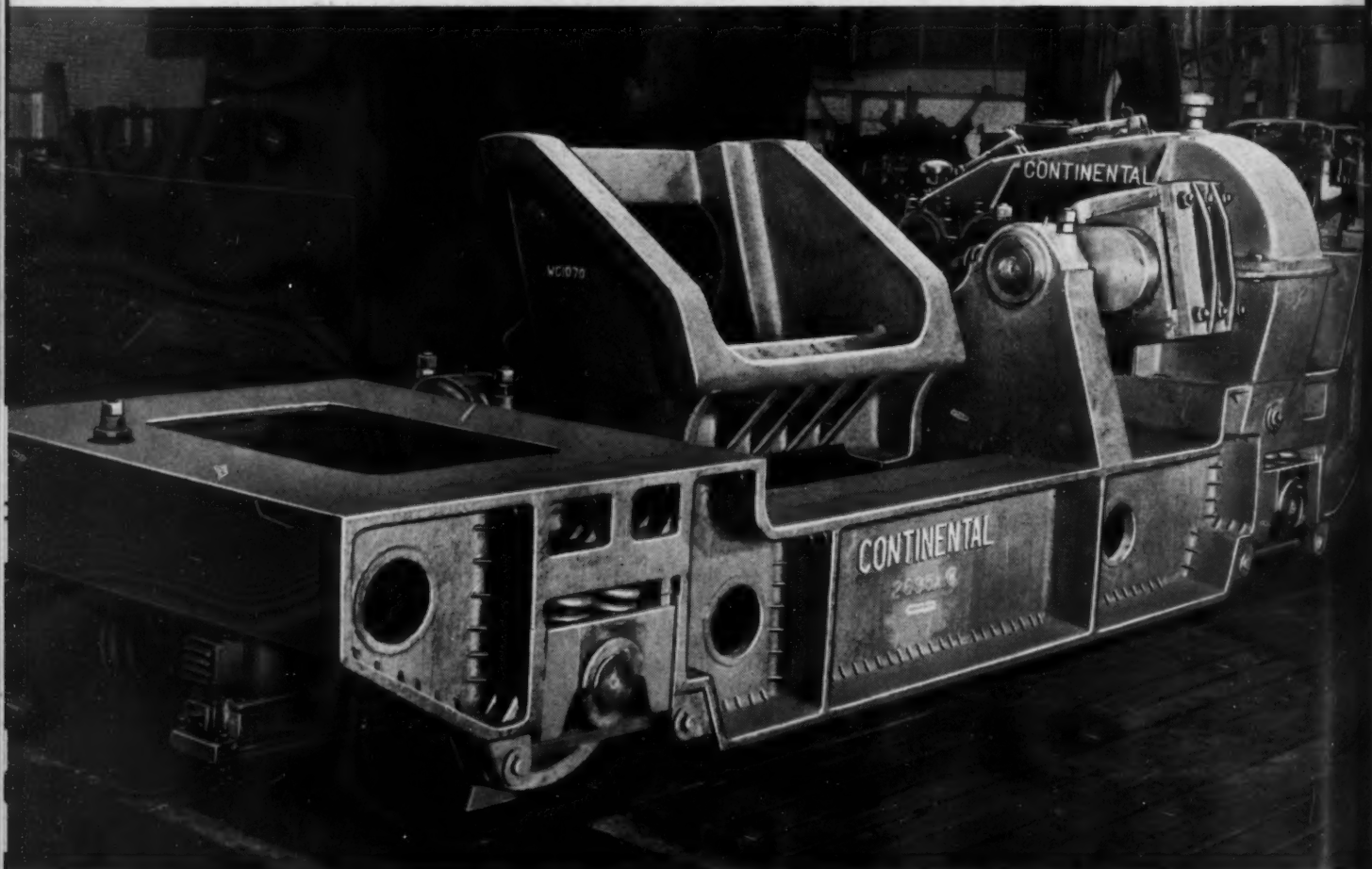
SALEM ENGINEERING CO. · SALEM, OHIO

INGOT BUGGIES

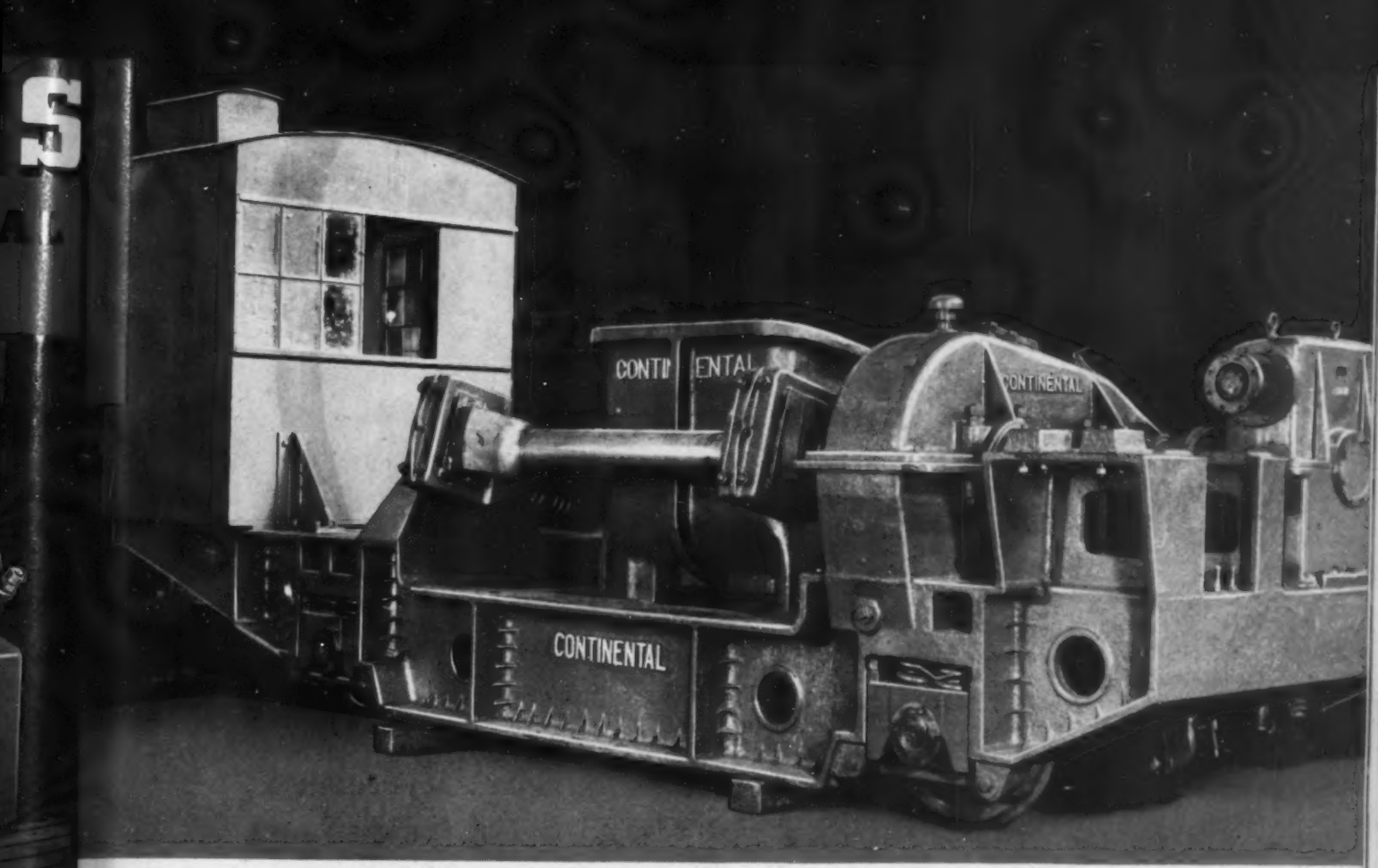
DESIGNED AND BUILT BY CONTINENTAL



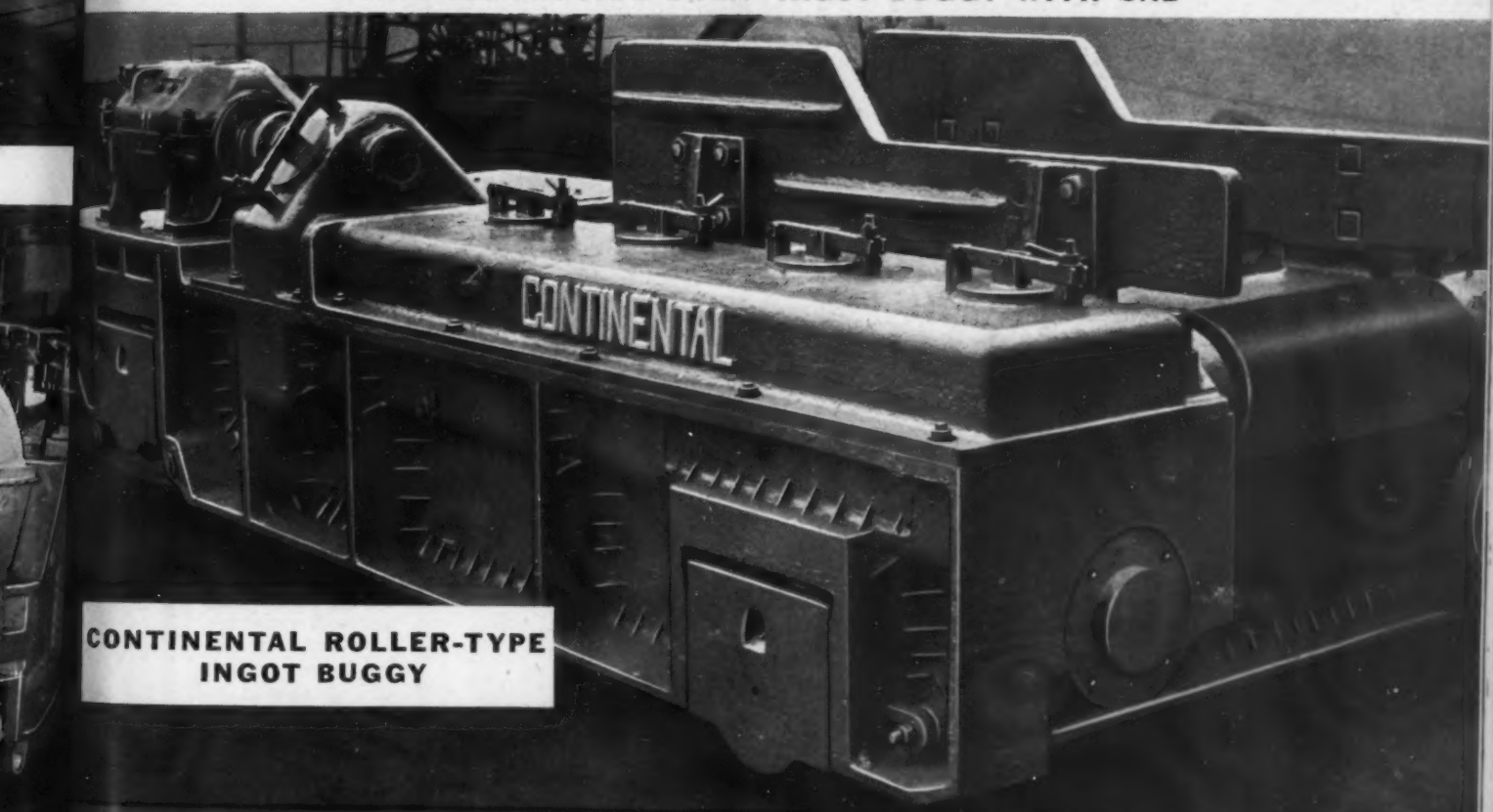
CONTINENTAL END DUMP INGOT BUGGY



CONTINENTAL REMOTE CONTROL SIDE DUMP INGOT BUGGY



CONTINENTAL SIDE DUMP INGOT BUGGY WITH CAB



CONTINENTAL ROLLER-TYPE INGOT BUGGY

CONTINENTAL

FOUNDRY & MACHINE COMPANY

CHICAGO • PITTSBURGH

Chicago Works
East Chicago, Ind.

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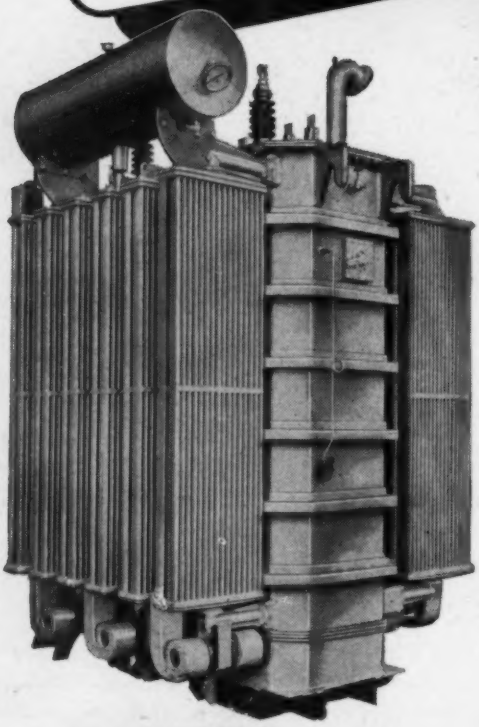
Wheeling Works
Wheeling, W. Va.

Warwood Works
Wheeling, W. Va.

A Complete Line of Wagner TRANSFORMERS for Industrial Use



Wagner's Diversified Line makes possible a wide selection from Standardized Designs

Industrial transformer application requires a large number of designs or combinations of partial designs. These designs are standardized in general for manufacture. In this way, Wagner is able to meet customers' exact specifications and requirements, yet use designs which have been pretested and proved in service—your assurance of satisfaction.

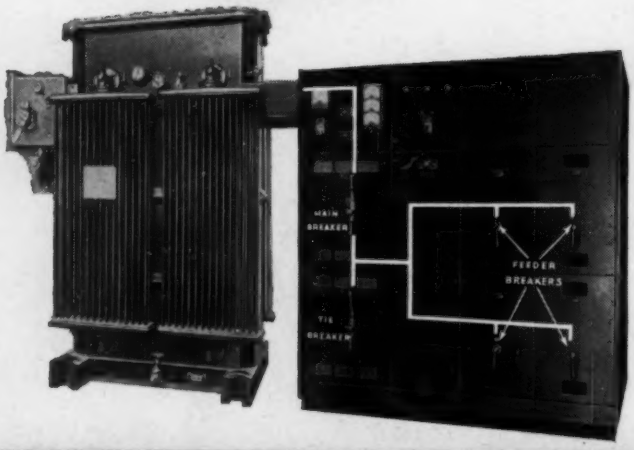
Whatever your particular industrial requirements may be, chances are you'll find in the Wagner line the exact type of transformer to meet your needs.

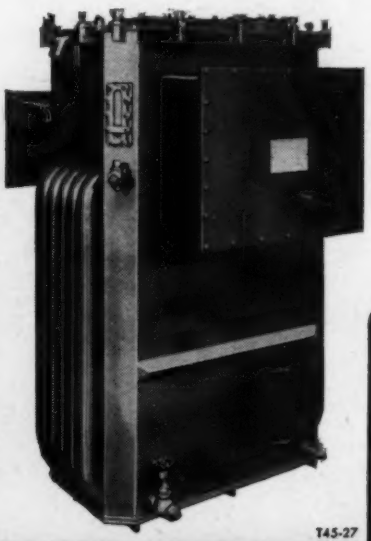
The Wagner Line Includes:

OIL-FILLED TRANSFORMERS **AIR-COOLED TRANSFORMERS**

UNIT SUBSTATIONS

NOFLAMOL TRANSFORMERS





T45-27

Write for **BULLETINS**

Bulletins TU-180 and TU-181 will bring you full information on Wagner distribution and power transformers. Write for a copy.

TRANSFORMERS are but one of several **WAGNER PRODUCTS** serving industry.

Other **WAGNER PRODUCTS:**

AIR BRAKES
•
BRAKE LINING
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HYDRAULIC BRAKES
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INDUSTRIAL BRAKES
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INDUSTRIAL BRAKE CONTROLS
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NOROL
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TACHOGRAPH
•
ELECTRIC MOTORS

Wagner Electric Corporation

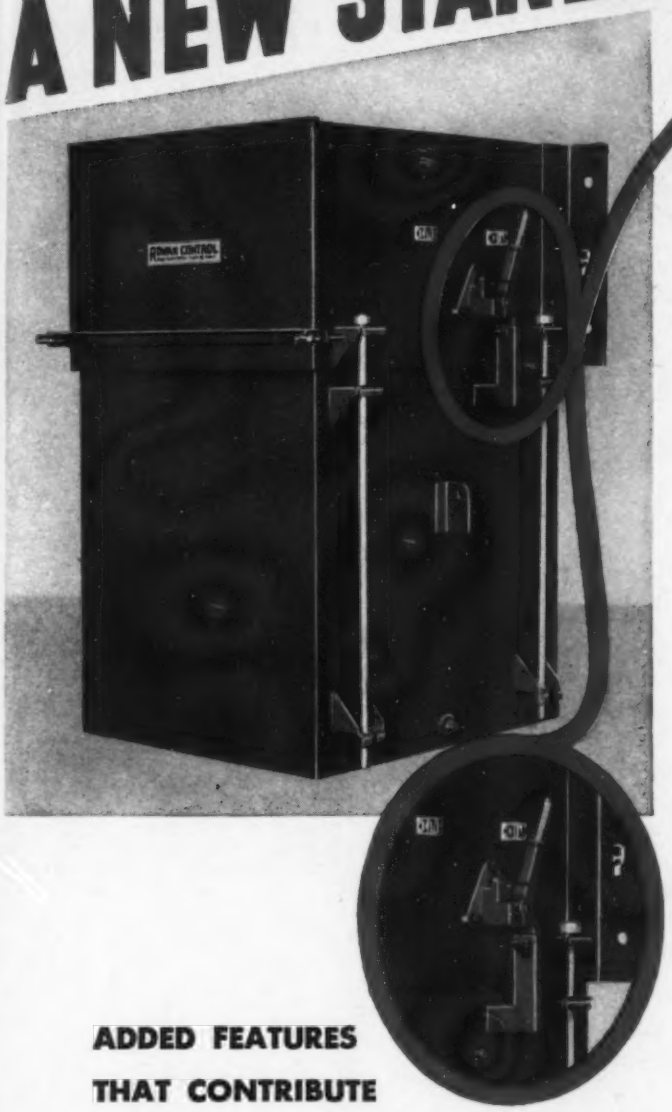
ESTABLISHED 1891

6483 Plymouth Avenue, St. Louis 14, Mo., U. S. A.

In Canada: Wagner Electric at Leaside, Ontario

ELECTRICAL AND AUTOMOTIVE PRODUCTS

Developed A NEW STANDARD IN SAFETY!



THE ROWAN 900-KBF COMBINATION, OIL IMMERSED, REDUCED VOLTAGE, IMPEDANCE TYPE AC MOTOR STARTER

This up-to-the-minute starter is a *combination* of our reduced voltage impedance starter and oil immersed safety disconnect switch with Rowan Air-Seal Fuses and Seal-Off Compartment for line, motor and control leads. Combining these Rowan advancements into one single unit conserves installation space and costs. *Maximum Safety is provided by mechanically interlocking the operating mechanism of the Safety Disconnect Switch with the Oil Tank.*

Reduced starting voltage is obtained by the use of continuous-wound coils with mechanical adjustment for varying the impressed voltage thereby eliminating tap failures.

The time of acceleration is determined by the motor and its connected load. There is no disconnecting of the motor from the line at any period during acceleration. This assures a minimum of line disturbance.

For safety, smooth acceleration, continuity of service and low overall cost—This ROWAN Type 900-KBF Combination Reduced Voltage Starter "Tops them all." Complete detailed information sent on request.

ADDED FEATURES THAT CONTRIBUTE TO SAFETY, LOW INSTALLATION COSTS AND CONTINUITY OF SERVICE

1. **Safety disconnect switch is completely interlocked with the oil tank in raised or lowered position—positive line disconnection.**
2. **Magnetic overload relays, combination of inverse time element, instantaneous operation—automatic Reset.**
3. **Rowan Air-Seal Fuses—A proven short circuit protection.**
4. **Fully automatic—Push-Button Operated.**
5. **Oil Immersed for maximum safety and protection.**
6. **Enclosure is of dust-tight construction.**
7. **Seal-off Terminal Compartment arranged for top and bottom conduit connections.**

More than a generation devoted to the design and manufacture of Oil Immersed AC Motor Controls.

ROWAN CONTROL

THE ROWAN CONTROLLER CO., BALTIMORE, MD.

Muscle is no match for machines

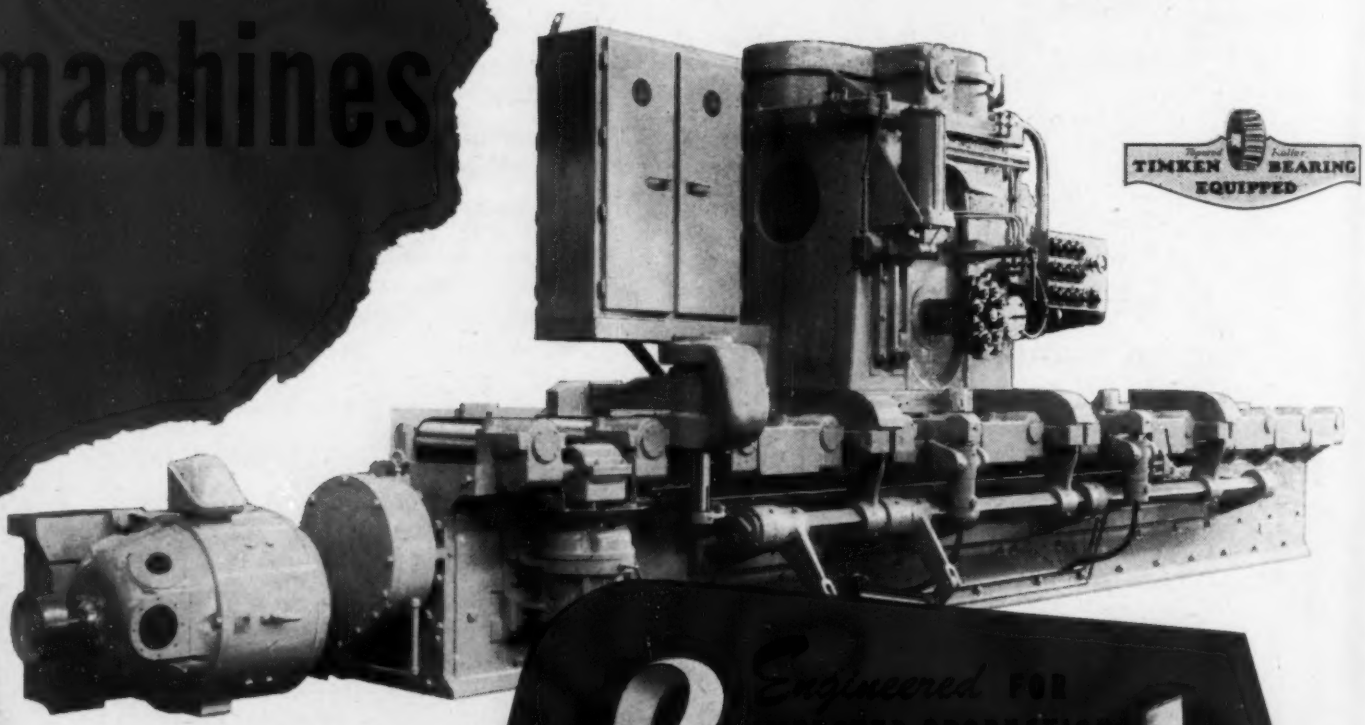
A subway could be dug by hand—if time and money were no object! But why sentence an army of men to years at hard labor when there are rugged machines to do the job faster, better and at a fraction of the cost?

By the same logic, why should a steel mill continue the expensive, slow and gruelling practice of hand chipping billets, when BONNOT BILLETEERS are available?

THE *Bonnot* BILLETEER

BILLETEERS have been in use in steel mills for many years and everywhere the story is the same. Each machine is doing the work of a dozen or more men—and doing it better. They are not only saving time, money and manpower but also many billets on which cleaning would be prohibitive under other methods. One quickly-trained worker, freed from the brutal, back-breaking grind of hand chipping, operates a profit-making BILLETEER.

Write for complete information.



Engineered FOR

Bonnot

BUILDERS OF THE BILLETEER

CANTON 2, OHIO

FOR TOP STEEL MILL EFFICIENCY BONNOT'S THE BUY!

ADDRESS CORRESPONDENCE TO STEEL EQUIPMENT DIVISION

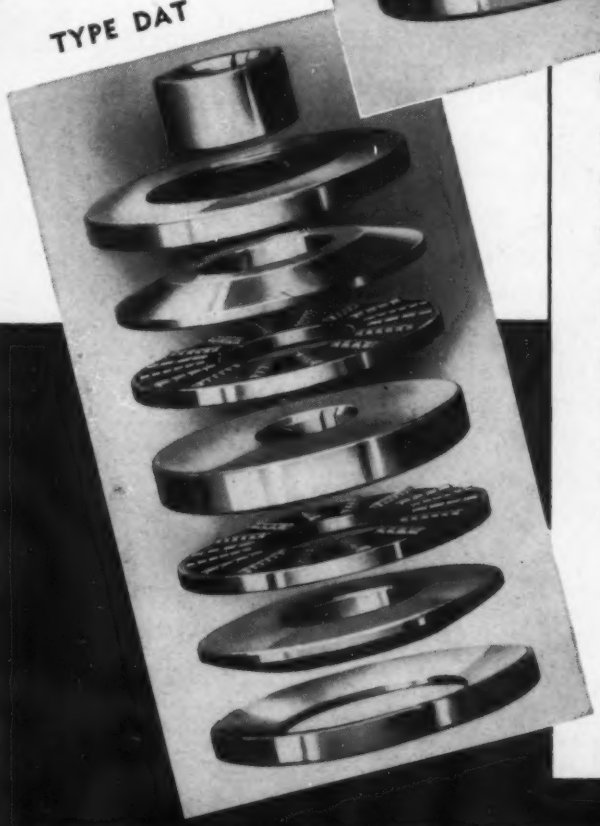
RIGHT ANGLE LOADING

Plus staggered rollers that will not "TRACK"...

TYPE T

TYPE AT

TYPE DAT



ROLLWAY

Solid-cylindrical-roller THRUST BEARINGS

When thrust loads are heavy . . . when maximum bearing capacity in minimum space is required . . . when the aim is to design "preventive maintenance" into the mechanism itself . . . Rollway solid cylindrical roller Thrust Bearings offer sound solutions to the basic problems. Here are the reasons why:

1. Rollway carries all loads at right angles to the roller axes.

2. Rollway solid-cylindrical rollers—staggered in position and varied in length, so as to cancel out "tracking"—are accurately spaced in machined-bronze retainers.

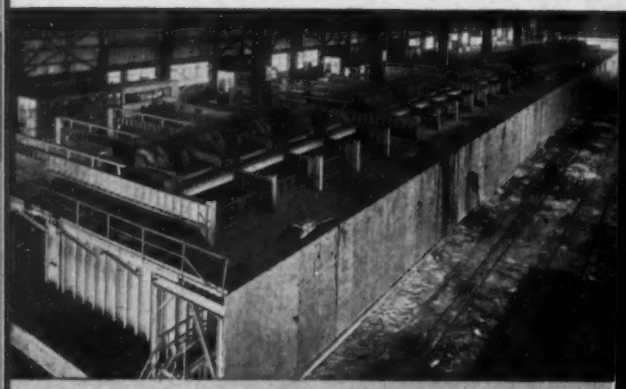
3. Thrust plates, held to extremely close limits of parallelism, afford a linear contact with the straight cylindrical rollers, doing away with Brinell effect and roller "pinch outs" with its consequent roller-end wear and rubbing friction.

Six basic types in many sizes to choose from. Send a print or detailed description for free bearing recommendation.

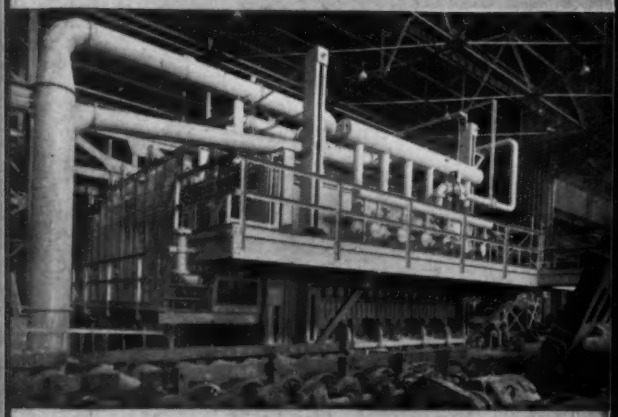
ROLLWAY BEARING CO., INC.
SYRACUSE 4, N. Y.

SALES OFFICES: Philadelphia · Boston · Pittsburgh · Youngstown · Cleveland · Detroit · Chicago · St. Paul · Houston · Tulsa · Los Angeles

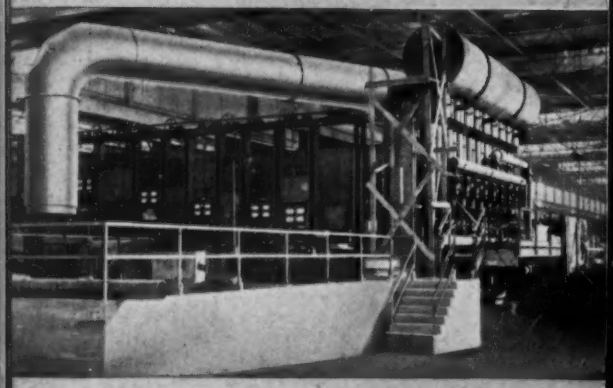
'SURFACE' SERVES WITH HEAT



"Surface" one-way fired soaking pits



"Surface" slab heating furnace



"Surface" billet reheating furnace

"Surface" continuous heat treating furnaces for plate

FROM INGOT TO FINISHED PRODUCT

Hundreds of installations, including the modern One-Way Fired Soaking Pits... Slab, Billet and Round Heaters ...Continuous and Batch Normalizers and Annealers — Muffle-type and Radiant Tube Fired, Controlled Atmosphere Furnaces... give outstanding proof of "Surface" acceptance wherever heat is used in the Steel Industry.

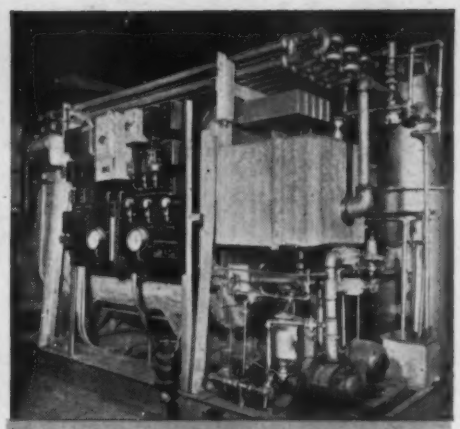
"Surface" collaboration with metallurgists and engineers in the metal producing and working industries, plus the years of constant laboratory research in the scientific application of gases, heat and mechanisms to the many heating problems, have resulted in continuous improvement in equipment to give the desired result. Only a few such installations are shown herewith, representative of "Surface" developments in the industry.

Now, when quality tonnage is paramount, "Surface" is ready with modern processes and methods to meet the world's demands.

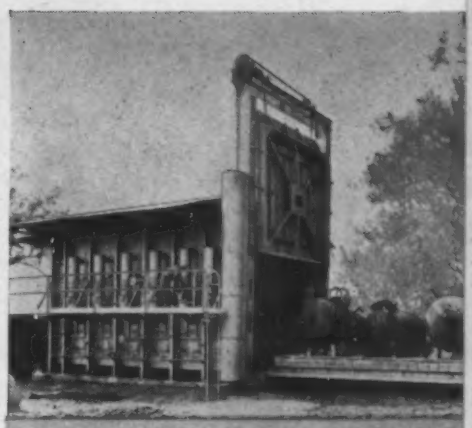
'Surface'

SURFACE COMBUSTION • TOLEDO 1, OHIO

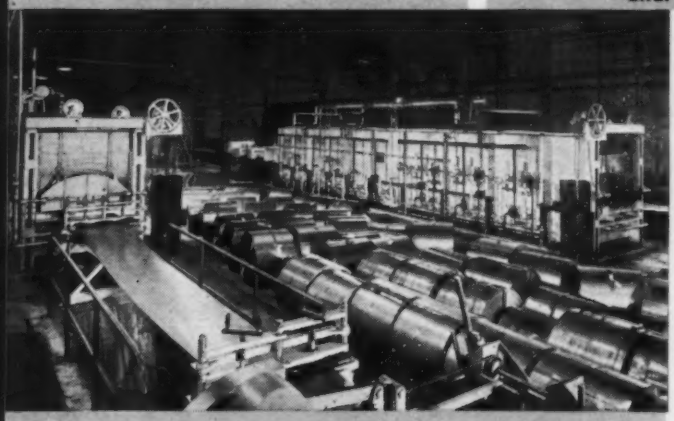
"Surface" rod annealing in pit type convection furnaces



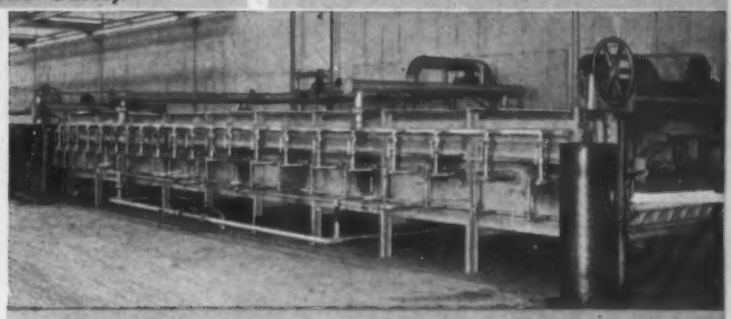
"Surface" prepared gas generating equipment (NX, RX, DX and Char-Mo Gases).



"Surface" stress relief furnace

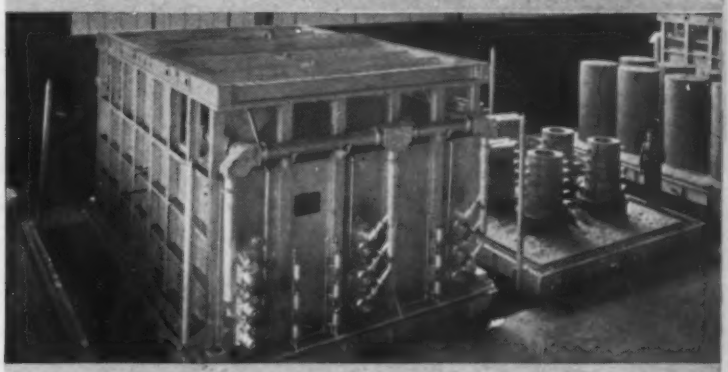


"Surface" continuous controlled atmosphere strip annealing and normalizing furnaces

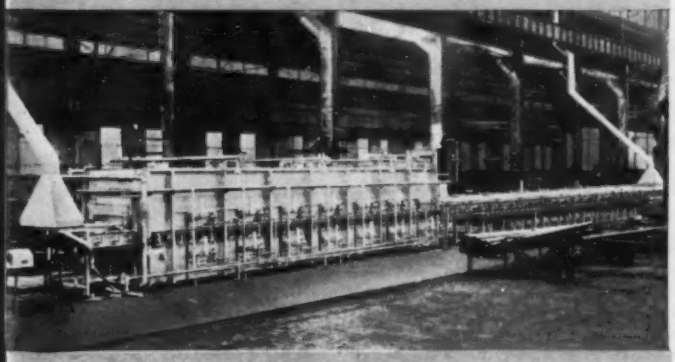


"Surface" wire patenting furnace

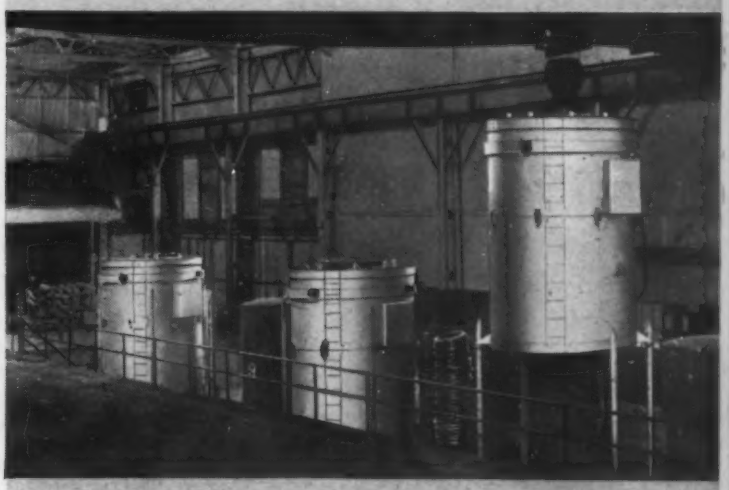
"Surface" high alloy rod and bar atmosphere annealing lift-cover with car-bottom furnace



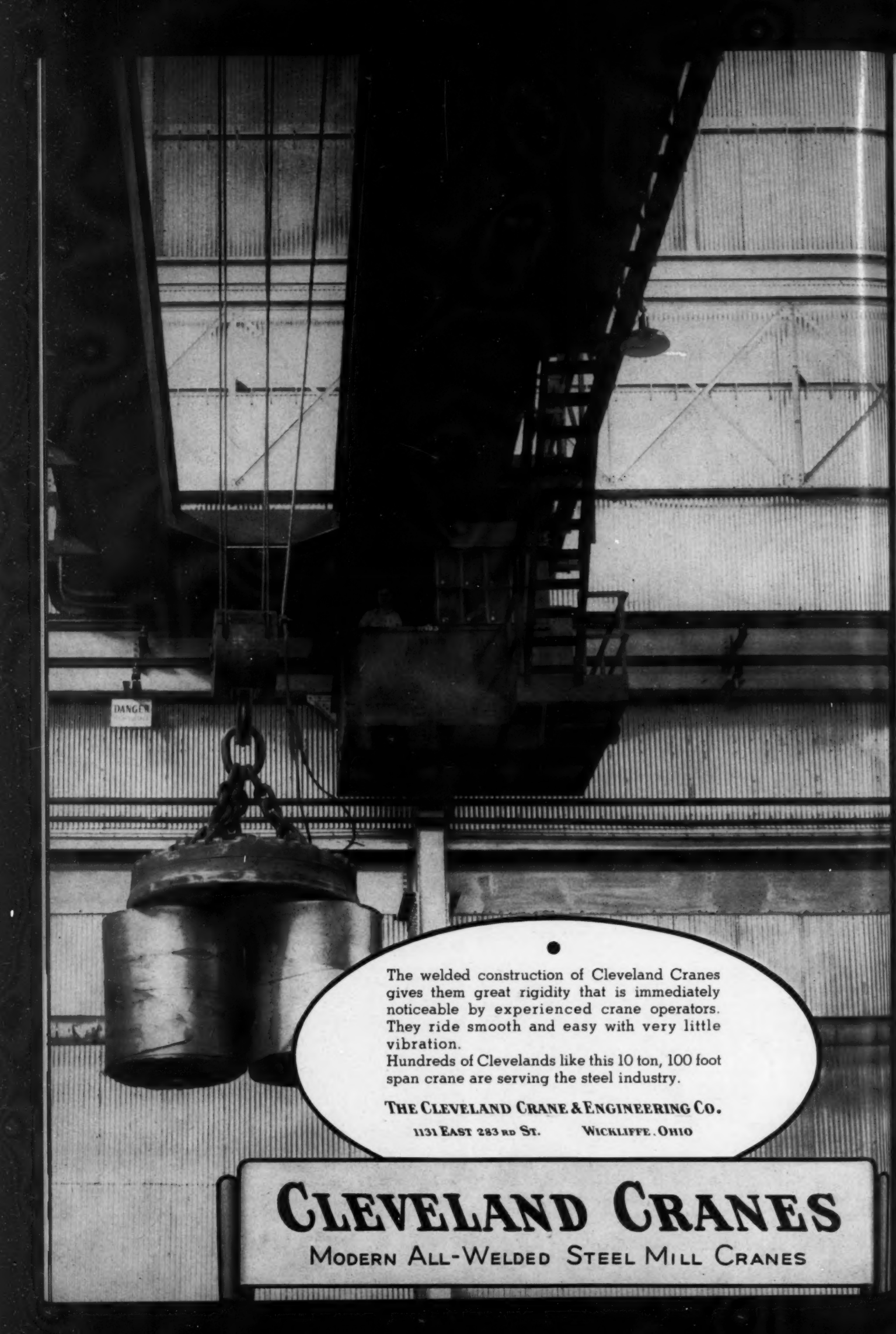
"Surface" controlled atmosphere coil and sheet annealing covers



"Surface" bright annealing and normalizing furnace for tubing



"Surface" controlled atmosphere wire and rod annealing furnaces



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IT used to be considered an honor for a worker to be singled out for promotion to foreman, and men used to jump at such chances. With the union ruling that a man loses all seniority upon becoming a foreman, however, some difficulty is being encountered in persuading men to accept a foreman job. From the worker's viewpoint, advancement is becoming a liability, because he is thereby losing security. Whether this security is real or fancied is beside the point — the idea exists. With some justification, the worker believes that, come a depression, he will be assured, through his union, of some work which might formerly have been done by the supervisory personnel, whereas the foreman, without seniority or security, will be laid off. And this reasoning is the strongest argument the unions have in their move to unionize foremen. We heartily agree with the statements of Clifford F. Hood, published elsewhere in this issue, concerning the impossibility of allowing supervision to pass from under the control of management. Management, however, might well look over the possibilities of security for their supervision, if a future dearth of supervisors is to be avoided.

▲

PAMPHLETS issued by the Department of Commerce to guide those who plan to establish small businesses of their own include these profound statements:

"An owner's survival in business depends upon his making a reasonable profit, and profits result from careful pricing."

"A net profit is provided only to the extent of the amount remaining in the selling price after the total of all expenses and the direct cost of the merchandise have been subtracted."

We would imagine that the same rules might be used to guide large corporations, who are at present being exhorted to raise wages without raising prices.

▲

PERHAPS it is this same idea that large enterprises have some special magic that led the Surplus Property Administrator to state that the United States Steel Corporation is the only company capable of operating the Geneva plant without subsidies in one form or another.

▲

INCIDENTALLY, Cyrus Eaton, Cleveland financier, told a Senate committee that $7,500,000-9,950,000 was the real economic value of the Kaiser steel plant at Fontana, California, and that the Geneva plant should remain government property, to be held as protection in case of another war.

▲

A REPORT on the Geneva plant, made for RFC by the Arthur G. McKee Company, gives $190,355,066 as the actual cost of the present plant, $134,000,000 as the replacement cost of the present plant, and $121,500,000 as the cost of an equivalent plant. The report also sets forth two reconversion plans, costing $37,000,000 or $30,000,000 respectively, to complete the plant with facilities for the production of plate, strip and sheets, tin plate, forging billets, and seamless pipe, or alternately, electric welded pipe.

▲

FOR the first time in its history, the Tennessee Coal, Iron & Railroad Company is bringing in iron ore from outside Alabama. To meet a shortage caused by lack of ore miners, 200,000 tons of Lake ore is on its way to Birmingham furnaces.

▲

ADD postwar reconversion: Youngstown Sheet and Tube Company is proceeding with expansion of facilities for cold rolled strip and wire drawing, thus raising their capacity for finished products.

Sharon Steel Corporation has purchased the Farrell works of Carnegie-Illinois Steel Corporation, thus acquiring two 800 ton blast furnaces, fifteen 105 ton open hearth furnaces, a 36 in. blooming mill and billet mills, with an annual capacity of 484,500 gross tons of semi-finished products.

Wheeling Steel Corporation is planning the purchase of the Mingo works of Carnegie-Illinois Steel Corporation.

Bethlehem Steel Company is proceeding with its rehabilitation program in bar mill facilities. The program includes the installation of a new 10 in. bar mill to replace old 8 and 10 in. mills, installation of additional soaking pits and a hot scarfing machine on the 40 in. blooming mill, and the installation of vertical roll stands in the 30 in. continuous billet mill, as well as many other improvements.

▲

ORDERS have been booked on the Pacific coast for more than 100 carloads of flat and corrugated aluminum roofing sheets. The sheets, .019 in. gauge, are to be produced at Alcoa, Tennessee, by Aluminum Company of America, who indicates that the Trentwood plant will also be operated should the demand warrant.

▲

SPONGE iron comparable in quality to that made in Sweden can be produced by carbon reduction in common shale-brick plants without alteration of the plants, according to Bureau of Mines reports of experiments. These experiments are discussed in Report of Investigation No. 3819, 3822, and 3824, which may be obtained from the Bureau of Mines, Department of the Interior, Washington 25, D. C.

▲

TO show the enormity of the accident toll and to emphasize the importance of preventing accidents, the National Safety Council compares total World War II casualties (December 7, 1941, to August 14, 1945) of 1,070,524 with the home front accident toll of 36,355,000 for the same period.

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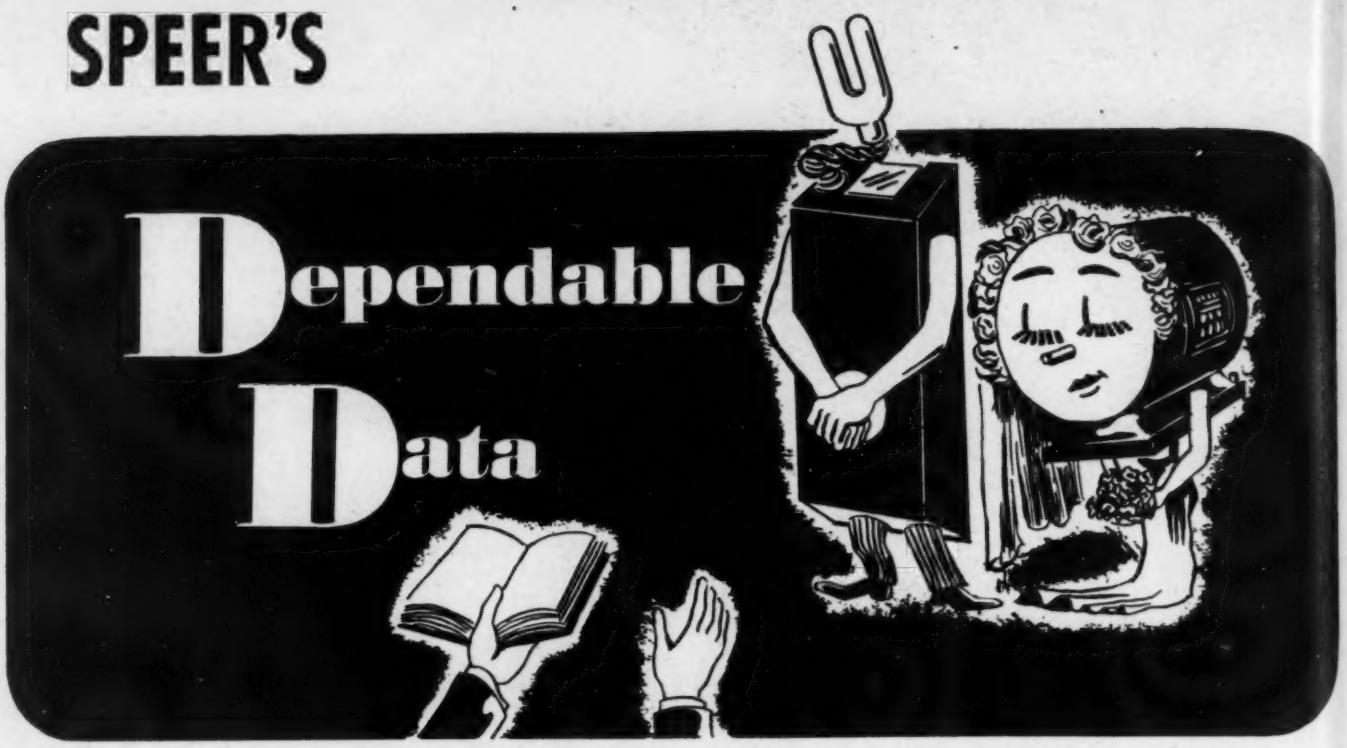

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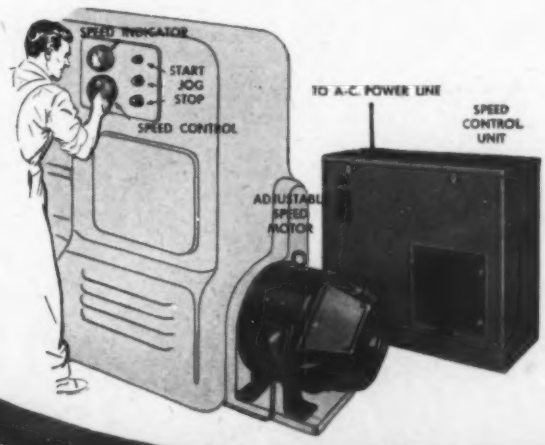

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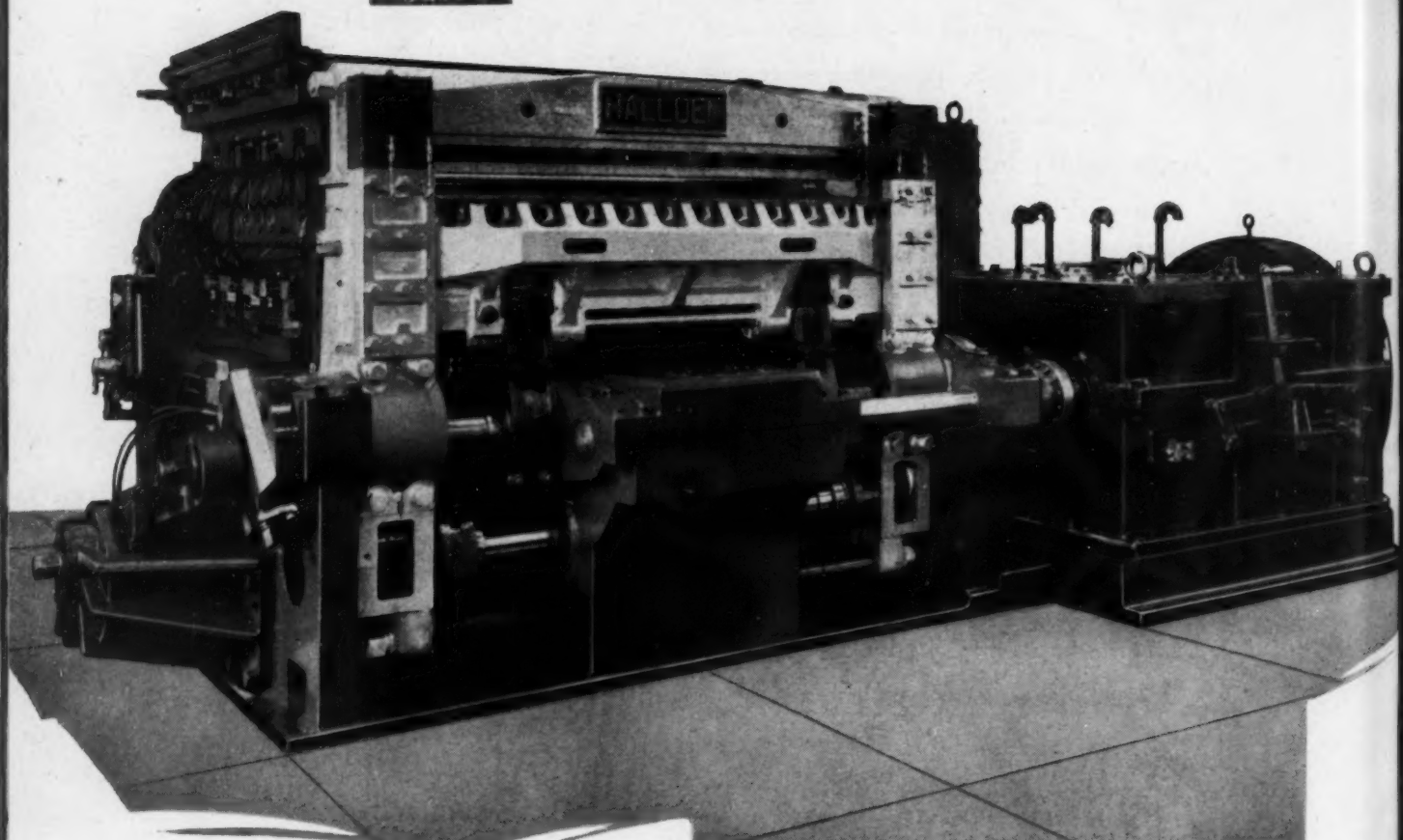

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Salvaging FORGED ALLOY *Steel Rolls*

. . . . in many cases, mills can reduce operating costs by salvaging "worn-out" rolls . . . . managements might well select mills which will permit the conversion of worn rolls from one mill to further use in other mills . . . .

by H. L. Watson, Jr., SUPERINTENDENT

SPECIAL PRODUCTS DEPARTMENT

THE MIDVALE COMPANY

PHILADELPHIA, PENNSYLVANIA

▲ THE salvaging of forged alloy steel rolls is the problem of returning to useful service rolls which have become unserviceable. The economics of the case is usually the deciding factor in determining whether a given roll is to be salvaged or scrapped. If the operating department's roll cost per unit quantity of material rolled can be reduced by salvaging the roll, then it seems highly advisable that an attempt be made to put the roll back into serviceable condition. In other instances, a pressing need for rolls to maintain production schedules may dictate that certain rolls be salvaged even though it is a relatively expensive undertaking. Since it is usually possible to get an old roll back into service in a considerably shorter time than that required to manufacture a new one, the reclamation of old rolls may aid in maintaining production.

The most important methods of roll salvaging are as follows:

(a) Simple regrinding after normal use.
(b) Simple salvaging of mill-injured rolls by grinding and etching.
(c) Stress-relieving treatments.
(d) Rehardening for use in same rolling mill.
(e) Remodeling into smaller roll for use in another mill.
(f) Salvaging of either forged or cast back-up rolls by resleeving.
(g) Miscellaneous repairs.

Since the method of simple regrinding is carried out daily in every roll user's grinding shop, it will not be discussed in this paper.

Many rolls have to be scrapped prematurely because they have not been properly reground and etched after having been in wrecks. To determine whether or not an injured roll may be salvaged, the injury should first be located with respect to some reference point on the end of the roll, and a path ground through the injured area until the injury is no longer visible. The path should then be polished either with a mirror wheel or by hand with emery and crocus cloth. Etching with a 5 per cent nital solution will disclose any remaining traces of the original injury as black areas of altered martensite. Alternate grinding and etching should be continued until these darkened areas are no longer disclosed by etching. Since the altered martensite has a greater density than the fully hardened martensite, there is a definite strain in the metal wherever the darkened areas are in evidence. The strain is brought about by the attempt of the altered area to contract. This contraction is of course restrained by the surrounding uninjured metal. Often the strain has been so great that actual

Presented before A. I. S. E. ANNUAL CONVENTION, Pittsburgh, Pa., Sept. 25-27, 1944

cracking has occurred. To be sure that no cracks remain after the nital etch no longer indicates the presence of altered martensite, the injured area should be reetched with a 20 per cent aqueous solution of nitric acid and examined very carefully with a magnifying glass. The failure to entirely eliminate cracks, checks and altered areas will most likely result in the early spalling of the roll in service, whereas careful following of the foregoing procedure will reduce the probability of subsequent spalling to a minimum. This procedure applies as well to the mate of a roll which has failed.

Figure 1 shows a portion of the rolling surface of an injured 21 in. diameter work roll used in a tandem four-high mill. This roll was operating in the second stand when a severe wreck was caused in that stand by the breaking of one of the rolls in the first stand. This photograph was taken after the strip which was welded to the surface during the wreck had been removed and the injured area etched with 5 per cent nital. The darkened area of altered martensite is covered with cracks and one portion of the surface has come off. This roll was salvaged by the removal of .100 in. from its diameter in the manner previously described. Although the injury to the mating roll was not as severe as that to the first roll, it nevertheless, required the removal of .075 in. from its diameter to eliminate the last traces. Both rolls were given a stress-relieving treatment prior to final regrinding.

Figure 1 — Injury on face of 21 in. diameter work roll used in a tandem four-high mill (5 per cent nital etch).

▲

Figure 2 — Surface spalling resulting from grinding wheel burns (5 per cent nital etch).

The same grinding and etching procedure should be followed on rolls which have been burnt with grinding wheels.

Figure 2 shows a shallow spall on the face of a roll caused by excessive wheel pressure. The circumferential dark bands show the traverse of the grinding wheel across the face of the roll. They appear after etching with 5 per cent nital solution as areas of altered martensite. Figure 3 is a grinding wheel burn caused by striking a stationary roll with a revolving grinding wheel. Burns of this type can sometimes be successfully removed by the process of alternate grinding and etching until darkened areas no longer appear.

Some plants have facilities for periodically stress-relieving forged alloy steel rolls. This treatment is beneficial to all rolls as well as those which have been subjected to abuse. The equipment should be of such a type that the hardness of the rolls is not modified to the point where they become too soft for the intended service.

Up to the present moment, we have discussed only the salvaging of forged alloy steel rolls which have not given their full expected life. The roll user's greatest opportunity to reduce overall roll costs is to find a way to salvage "worn-out" rolls, or rolls which have been reduced in diameter so that their hardness is no longer sufficient for the intended service. Such rolls are no longer economical to use since they mark very readily and have to be removed for regrinding after relatively short campaigns in the mill. They are, however, sometimes used in this condition when the user's inventory is low.

In many instances, the roll neck bearings and mill housings will accommodate a greater reduction in body diameter than the depth of hardness will permit. When such a condition exists, it may be worth the user's while to have the roll rehardened. Such a roll, rehardened and reground, may be expected to again give a good account of itself.

Some roll users have attempted to reharden and recondition their own rolls but it is better to have this work done by roll manufacturers who have the experience and the specialized equipment required for this type of work.

A roll intended for rehardening is first inspected for size and condition. The actual dimensions, because of wear, are frequently at considerable variance with standard blueprint sizes and tolerances. These dimensions, particularly the journal diameters, must be obtained so that the roll maker will know what work is required to restore the roll to serviceable condition. The inspection for condition includes a careful examination

Figure 3 — Grinding wheel burn caused by striking stationary roll with revolving grinding wheel (5 per cent nital etch).

of the roll body and locates any spalled or injured areas which must be removed prior to rehardening.

After inspection, the roll is annealed and if necessary, machined preparatory to hardening. It is necessary that sharp corners on the ends of the body be eliminated and that any spalls, cracks or other injuries be removed. After hardening and drawing to the specified hardness, the roll is ready for finish grinding.

The quenching of a piece of steel usually produces more or less distortion. The hardening of rolls is no exception to this rule, even though all possible precautions have been taken to keep this distortion to a minimum. To determine the distortion after hardening, the roll is indicated for concentricity and measured for out-of-roundness. It is usual to set the center of the bearing fits on both ends dead true and then to check and record eccentricity at the center and both ends of the body, on the set-downs, in the grooves, and on the extreme ends. Assuming that the maximum allowable deviations from blue-print dimensions are known, the roll is then ready to be refinished.

Work rolls for reversing four-high cold finishing mills require the closest adherence to original tolerances. Figure 4 is a sketch of a roll of this type. Too much deviation from the original tolerances of the bearing fit cannot be allowed, since only a small amount of bearing clearance can be permitted on a mill producing finished strip. If the portion of the journal shown as dimension C has been reduced by wear before the roll was returned for rehardening and distorted during rehardening, it will have to be restored in some manner to the original size. Section D is the location for a relatively loose fitting ring which holds the bearing in place. It usually does not matter a great deal if this portion is somewhat under tolerance. However, some mills require that D as well as C be maintained full size. The shoulder B can be somewhat undersize unless it is a seal-fit, in which case it must be full size.

It is to the advantage of the user to give the roll maker as much leeway as possible with respect to tolerances required on rehardened rolls. As the number of dimensions demanding full size is increased, so will the price for reconditioning the roll be increased.

Occasionally a roll will distort so much the journals must be straightened before any other work is started.

Since the grooves shown as part E of Figure 4 can stand a liberal minus tolerance, it is only necessary that they be trued up to remove the eccentricity. The roll neck bearings are held in place by means of nuts which are fitted to externally threaded split rings which fit in these grooves. These split rings are self-aligning so additional clearance is usually permissible. The grooves are frequently employed as steady rest supports during the regrinding of the roll, in which case it is usually more important that both grooves on a given roll be the same diameter rather than any particular diameter.

The key-way sections at the ends of the journals which are shown as part F in Figure 4 are usually left as received from the user. Worn wobblers and splines have been restored to original dimensions by welding but this involves additional hazard and expense. If the eccentricity of the journals is small enough to permit the regrinding of the bearing fits, the eccentricity on the drive ends is generally small enough so that it requires no correction. Due to the universal joints on most mill drive couplings, a small eccentricity on the drive end is quite readily accommodated.

Although four-high single stand or tandem cold reduction mills usually employ the same type of work rolls as do four-high single stand reversing cold finishing mills, the maintenance of tolerances on the journals of the former is not as important as on the latter. The user often increases the tolerances on the bearing fits for rolls of this type. Frequently a journal .015 to .020 in. undersize will be acceptable. One user will accept them .045 in. under nominal dimensions and has rolls in successful operation with journals .060 to .070 in. undersize. When tolerances are increased in this manner and when the journals are not too badly worn, it is possible to reharden and regrind a cold reduction mill work roll without having to restore the journals to original sizes.

High-speed cold reduction mills cannot permit such eccentricity of the drive ends of the work rolls. Too great an eccentricity has caused spindle breakage as well as bad mill vibration. If the user of rehardened rolls insists that the rolls having the most eccentricity be used in the first stands of tandem mills, operating conditions are improved.

Figure 5 shows an old style two-high mill work roll which operates in plain bearings. A roll of this type can be reconditioned without the difficulties discussed in connection with four-high mill work rolls. Since the proportions of two-high mill rolls are more massive than those of four-high mill rolls, the tendency to distort during rehardening is reduced. The journals shown at B need only to be reground matching the two journals on a given roll at the same diameter. The small amount of eccentricity on the wobblers is usually of no consequence.

Another type of two-high mill work roll having tapered journals which operate in oil-type bearings is shown in Figure 6. Because both the angle of taper and the actual dimensions must be maintained, the reconditioning of rolls of this type creates special problems. Both tapered portions shown at L and M must have their diameters accurately maintained. Fortunately, the design of these rolls usually permits a liberal tolerance on the length of the short taper L adjacent to the body. This portion, which is a seal fit, usually has a liberal

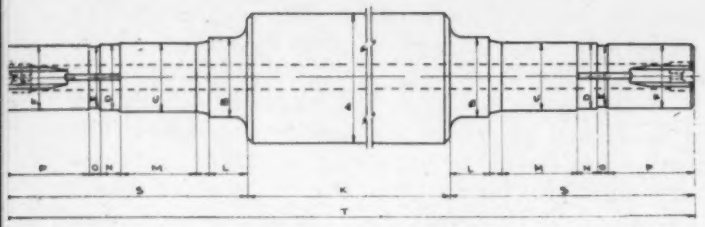

Figure 4 — Four-high mill work roll.

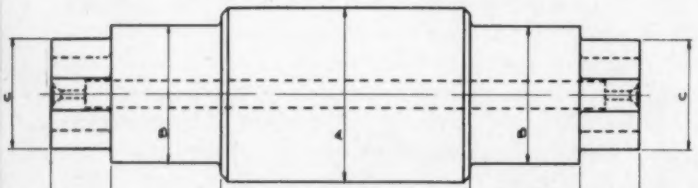

Figure 5 — Two-high mill work roll.

Figure 6 — Tapered journal work roll for two-high mill.

plus or minus tolerance. By taking advantage of this tolerance, the tapered bearing fits M can be reground. By this means .006 to .007 in. may be ground off the diameters of the tapered journals without reducing them below original blue-print dimensions. Since a good many rolls of this type have rather massive proportions, the small amount of eccentricity caused by rehardening can be taken care of as described.

In cases where the eccentricity of the tapered portions exceeds .006 or .007 in., it is sometimes possible to shorten the body and then regrind the journals to size. We know of rolls in operation on which the body length is as much as ¼ in. shorter than called for on original blue-print dimensions. This cannot be done with rolls from mills which require that the bearing chocks be keyed to the mill housings unless it is permissible to key only one of the two chocks.

We have considered only the salvaging or reconditioning of forged alloy steel rolls which are to be used in the same mill from which they were removed as being unsatisfactory for further economical operation.

We will now consider what can be done with rolls which have been reduced in diameter so that the bearing chocks are face to face, thereby eliminating any possibility of salvaging them for use again in the same mill. Such rolls may already have been rehardened before this diameter has been reached. Assuming that the user has several mills using different sized rolls, it may be possible to convert the larger rolls into rolls for the smaller mills. This can be determined by comparing scaled layouts of the present and proposed rolls. The internal as well as external dimensions must be compared to be sure that some cross-section of the remade roll is not going to be too small. If remnants of the original splines, key-ways, and grooves will still remain, it is possible they will not interfere with its operation as a remade roll. In many cases, where no traces of previous splines, etc. remain, such a remade roll cannot be distinguished from a new one.

The work required to make a larger roll into a smaller one is considerably greater than that required for rehardening and reconditioning. The outstanding difference between the two procedures is that a great deal more machining is required to remake a roll than to recondition one. This extra machining affects the price with the result that a remade roll is somewhat more expensive than one which has been reconditioned. The difference in size between the original roll and its modification should not be so great that the excessive machining required makes the cost prohibitive. The journals of a remade roll usually have to be completely remachined. Besides turning and grinding to size, the work of conversion includes all of the miscellaneous machine work of milling splines and key-ways, drilling and tapping holes, machining grooves, fitting plugs, and making and fitting thrust rings if these are required.

Some plants have such an assortment of rolling mills that many possibilities are open for the salvaging of "worn-out" rolls either by rehardening or remaking. One works in particular has a series of four different sized mills with rolls of the same body length. The dimensions of the rolls for these four mills are such that the largest roll can be remade for successive use in each of the three smaller mills. Although the largest of these rolls has a rather large bore for final conversion to the smallest size, we know of no operating difficulties brought about by this condition.

Another plant has its 18½ in. diameter four-high temper mill work rolls remade into 16½ in. diameter cold reduction mill rolls. Disregarding body diameters, these two rolls are identical in every respect with the exception that the journal and shoulder diameters of the temper mill rolls are $\frac{1}{32}$ in. greater than the corresponding portions of the cold reduction mill rolls. This is just enough difference to take care of the distortion caused by rehardening and makes it possible to refinish the journals to the new sizes. The spline drives, key-ways, and thrust rings are the same for both rolls so that they do not have to be remachined.

Some mills are designed to operate with unmatched work rolls. One operator of a four-high four stand tandem cold reduction mill does this by the simple expedient of driving only the bottom work rolls. The top work rolls are not driven and are of an entirely different design from the bottom rolls. When a bottom roll can no longer be rehardened for additional service as a bottom roll, it can be remade into the smaller top roll. Larger rolls from other mills in this roll user's plant are often remade into either top or bottom work rolls for the tandem cold reduction mill.

It is sometimes advisable to recondition certain rolls

even though their hardness and diameter are still satisfactory. This condition can arise when a roll has been subjected to a severe injury and, as a consequence, the operator is afraid to use it again because of the likelihood of its spalling. If such a damaged roll were placed back in service, it might very readily spall because of stresses locked up in the injured or bruised surface. On the other hand, if this roll safely negotiates the rehardening process, it is not nearly as likely to fail as would be the case if it were not so processed. If any sub-surface lesions of the metal had occurred, spalling or breaking during rehardening would likely take place. This reprocessing also entirely removes all strains resulting from the injury. In this manner rolls have been salvaged with bent and twisted journals as well as rolls with the strip welded to their faces. They performed satisfactorily after this reprocessing.

Sometimes because of faulty lubrication, the journals of two-high mill rolls which operate in plain bearings become badly heat checked. Figure 7 shows such a roll. A roll in this condition may fail by the entire journal cracking longitudinally from individual heat checks growing into one continuous crack. Figure 8 shows such a journal. Although many rolls with checked journals have remained in service without failure, the safest procedure is to have the journals turned down and heat treated forged steel sleeves shrunk on them. The wall thickness of the sleeve must be great enough so that it will not crack, yet thin enough so that the roll journals will not be unnecessarily weakened.

The salvaging of damaged or worn-out rolls is by no means confined to work rolls. Back-up rolls which have been badly spalled or which have been reduced in diameter to such an extent that they are no longer serviceable may, in many cases, be salvaged by having the roll manufacturer shrink heat treated forged steel sleeves on them. This can be done with either forged or cast back-up rolls. In either case, the original roll is turned down for use as a mandrel on which a sleeve is to be shrunk. The wall thickness of the sleeve should be neither too thin, which would cause it to "roll out" in service and become loose, nor too thick, which would both weaken the mandrel and add to the cost. In general, the wall thickness should be kept at the minimum permitted by the other factors.

When it is impossible to obtain a proper wall thickness without weakening the mandrel too much, or for some other reason, the desired wall thickness may sometimes be attained by increasing the outside diameter of the sleeve to a size larger than that of the original roll. Sometimes the diameter of the built-up roll may be increased two to three inches over the diameter of the original one piece back-up roll.

The sleeving of back-up rolls is particularly applicable to the larger sizes and is seldom recommended on back-up rolls less than 28 in. in diameter. There are, however, a number of successful exceptions to this. Two piece back-up rolls 18 in. in diameter and even as small as 14 in. in diameter are in use.

The sleeve must be shrunk on the mandrel with a shrinkage allowance sufficient to prevent slippage and yet not so great that the sleeve will split in service. The shrinkage must also be uniform. At first, sleeve-type backing-up rolls were put together with a simple shrink-fit and no locking devices. With the gradual increase of mill speeds resulting in a greater heating up of the rolls in operation, some sleeves slipped endwise on the mandrels. Various locking devices have been applied to prevent this movement of the sleeve relative to the mandrel. Some of the earlier locking devices were only partially successful in that a few sleeves still slipped. The newer ideas for preventing this movement have proven successful. Several different methods are in current use. The use of any particular design of locking device depends on the design of the roll and upon its hardness. Regardless of which device is selected, the sleeve should be locked to the mandrel at one end only. The other end should be free to move with temperature changes. If both ends are secured, breakage of the roll may occur.

The hardness of sleeves up to 36 in. diameter for use in cold rolling is usually specified to be 80 to 90 scleroscope, although a number of mills have found that 70 to 80 is amply hard. The larger sleeves used in cold rolling vary in hardness from 58 to 80 depending upon the diameter of the work rolls and the type of work being produced on the mill. Forged steel sleeves are also shrunk on back-up rolls used in hot mills. For this service, the scleroscopic hardness is usually less than 70.

Some cast back-up rolls, after having been "worn-

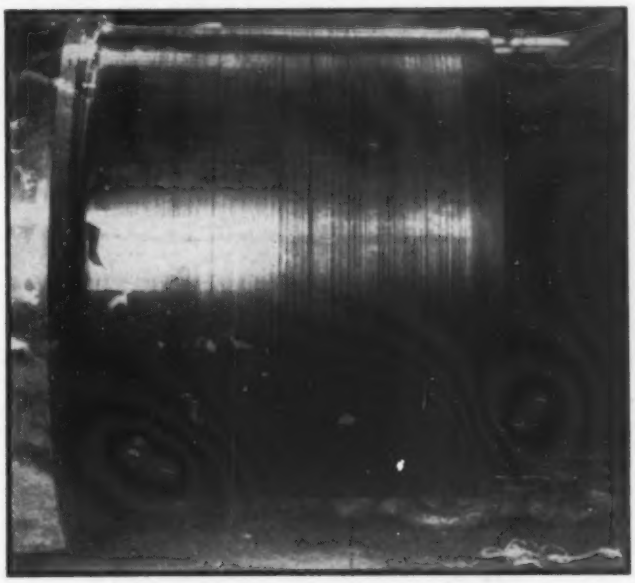

Figure 7 — Two-high mill work roll with badly checked journals.

▲

Figure 8 — Continuous crack on journal caused by the growth of numerous small heat checks.

out" as one-piece rolls, have been made into mandrels and have been resleeved three or four times before they had to be scrapped for worn journals or because their body diameters had been reduced too much. Some plants have found the built-up back-up roll to be so successful and economical that they order new cast mandrels and send them to the forged roll manufacturer for sleeving. Where mill loads are high and where there has been considerable breakage of cast mandrels, heat treated forged steel mandrels have been used to prevent further failures.

In this paper we have attempted to show that rolling mills can, in many cases, reduce their operating costs by salvaging supposedly "worn-out" rolls.

In planning postwar expansion of cold rolling facilities, mill managements should endeavor to select the sizes and designs of mills which will permit the conversion of rolls "worn-out" in one mill to further use in other mills.

DISCUSSION

PRESENTED BY

JOHN A. SUCCOP, Heppenstall Company, Pittsburgh, Pennsylvania

L. F. COFFIN, Superintendent of Mechanical Department, Bethlehem Steel Company, Sparrows Point, Maryland

J. A. LAFFERTY, Superintendent Roll Shops, Republic Steel Corporation, Warren, Ohio

M. D. STONE, Manager, Development Department, United Engineering and Foundry Company, Pittsburgh, Pennsylvania

THOMAS SMITH, Roll Designer, Great Lakes Steel Corporation, Ecorse, Detroit, Michigan

C. R. HAND, Lubrication Engineer, Bethlehem Steel Company, Sparrows Point, Maryland

LOUIS MOSES, Superintendent, Rail Mill and Roll Department, Bethlehem Steel Company, Sparrows Point, Maryland

H. L. WATSON, JR., Superintendent, Special Products Department, The Midvale Company, Philadelphia, Pennsylvania

J. A. Succop: I was especially interested in Mr. Watson's description of the development of back-up rolls using shrunk-on sleeves, as our company manufactures composite back-up rolls but does not manufacture work rolls.

In examining roll sleeve failures, we have noticed invariably, that the nuclei of the failure of cracked sleeves starts internally and progresses with a fatigue type of fracture, and I would like to ask the speaker if he would care to elaborate on his ideas as to what is the cause of these internal fatigue fractures.

The second question I have in mind pertains to the hardness of back-up roll sleeves. Mr. Watson recommends a hardness up to 90 Shore hardness for sleeves.

I am interested to know why it is necessary to think of sleeves requiring such a high hardness, and also whether the high hardness promotes a tendency toward splitting of the sleeve in the early service life of the roll.

L. F. Coffin: I would like to know whether the author knows of any steel plants which have retreating equipment installed in their own plant for heating and retreating damaged rolls. The author's method of etching and regrinding is interesting.

In some cases in breakage of necks on back-up rolls where the necks were originally sleeved, we drew out the curve of uniform stress and found that the stress line passed outside of the fillet, proving that that point was the weakest one of the roll. By eliminating the application of the sleeve to the neck and casting a solid roll, the line of uniform stress passed inside of the fillet and hence breakages at that point were expected to be reduced.

J. A. Lafferty: We have reconditioned rolls for a good many years — that is, have had them rehardened, reconditioned, and remade into smaller size — and so far we have had a good bit of luck with it, except with some necks for oil-film bearings, where we had a lot of distortion and had to shorten the body, as Mr. Watson stated.

There are some questions I would like to ask about welding. Mr. Watson said welding of wobblers and splines was hazardous. I would like to inquire if that was before or after hardening. He also mentioned in his paper that some mechanical departments will take roll necks .045 to .070 in. undersize. I wish I had a mechanical department like that to work with.

In the remaking of rolls, is it advisable to send the roll back to the roll maker? I have sent a maker's roll back to a competitor and it split.

Sleeves for back-up rolls have caused us plenty of trouble. By slipping endwise, I have had one crack the full length, but the worst trouble is creepage. The sleeve crawls on the mandrel around the periphery of the roll. It causes the gage to jump all over the lot, especially when you have it in a four-high cold reduction tin mill.

I saw one manufacturer grinding the sleeve internally and the mandrel on the outside to mirror finish. His idea was that the sleeve would not creep. I would like to know what Mr. Watson thinks about that.

M. D. Stone: I would like to ask Mr. Watson two questions. He mentioned resleeving necks in case of fire checking. Has he established possibly what the minimum of thickness of sleeve is that he could put on there that would not creep, as a satisfactory solution to the resleeving problem?

Along that line and along the lines that Mr. Lafferty mentioned, are there any limits established as to creeping of sleeves on the roll body itself, probably from the point of view of thickness of the sleeve as well as the internal finish? I am just wondering whether a rough finish there would not be more satisfactory than the very smooth grind that this one steel mill used in resleeving.

Thomas Smith: I might say that we have not had any luck sleeving back-up rolls. We have sleeved them and they have split lengthwise. We have had them creep, which throws the roll out of round.

I had one particular roll that we put a sleeve on and the first time we put it in the mill the neck broke off. I took the sleeve off that body and put it on another one and the second time in the mill the neck broke again, so I am not much enthused about sleeving of rolls because we find that the sleeve costs almost as much as a new roll and I cannot see the advantage of putting a new sleeve on a roll that has worn-out necks.

C. R. Hand: I would like to ask Mr. Watson what

method he uses to determine whether the neck is cracked before they go ahead and reharden it or resleeve it.

Louis Moses: Some time ago it was thought that the bored holes in hardened steel rolls could be eliminated to save machining time as the practice of internal cooling had been discontinued. I would like to ask if I was correct in advising that the bored hole was nevertheless necessary because of its aid in heat treatment.

The reported success in some quarters of the cutting tool field on deep freezing tools leads to conjecture if the same treatment of structure transformation would be beneficial to the performance of such rolls.

H. L. Watson, Jr.: Mr. Succop has asked why the nuclei for the failure of cracked sleeves is not on the surface. If a sleeve is subjected to a severe localized bruise, a sub-surface lesion may be produced which will become the nucleus of a detail type fracture which will ultimately result in failure of the sleeve. This lesion, or first rupture of the metal, will be sub-surface since the point of greatest shear is some distance below the point on the surface where the maximum overloading occurs.

As far as the hardness of sleeves is concerned, it might be said that the trend is toward sleeves having a scleroscopic hardness of less than 80. However, a number of the smaller mills still desire and specify sleeves to be furnished within the hardness range of 80 to 90 Shore. In most cases the actual hardness is much closer to 80 than it is to 90. These hard sleeves are required where the ratio of back-up roll to work roll diameter is great. In such installations the arc of contact between work roll and back-up roll becomes smaller, with the result that unit pressures are greater. This greater pressure requires higher hardness values in the sleeve so that rapid marking does not take place. These harder sleeves do not split if they are assembled properly and are not subsequently abused.

To answer Mr. Coffin's question, some few mills have facilities for the periodic stress relieving of rolls; most are not so equipped.

Mr. Lafferty has raised the question as to whether under-size wobblers on forged steel rolls should be welded before or after rehardening. If this has to be done, it is preferable that it be done prior to rehardening. Usually it is not worth while to attempt to salvage a roll which is so badly worn that it requires welding to restore portions to useable dimensions.

It is not necessary for a roll to be returned to the maker for reconditioning. We receive as many rolls of other manufacture as we do of our own.

Mr. Lafferty and Mr. Stone have both raised similar questions with respect to slippage and shrink fits on sleeve type rolls. Creeping of sleeves on mandrels has been experienced on some mills. This tendency might be reduced if it were possible to redesign the built-up roll with a thicker walled sleeve which would have less tendency to "roll out" and become loose. In most cases, it would be preferable to obtain this greater wall thickness by increasing the outside diameter, since reducing the bore size would tend to weaken the mandrel. On the other hand, in cases where the outside diameter cannot be increased, it might be possible to reduce the shrink-fit diameter without weakening the mandrel too much. Because of the great variation of dimensions and proportions on built-up back-up rolls no fixed rules have been formulated; each particular design must be individually worked out. Rapid, rather than gradual, warming up of the roll in the mill may cause temporary looseness which would permit creepage to start.

Too smooth a finish on shrink fit diameters on both sleeve and mandrel may permit slippage. If the surfaces are absolutely dry or even slightly rusty, any tendency to slip will be reduced. A ground finish is all right, provided it is not too smooth. A smooth machined shrink fit surface must be finished and checked very carefully. If the surface is composed of a series of fine tool marks, similar to a very fine thread, the size obtained will be that of the highest ridges. These ridges will collapse during shrinking with the result that some of the shrinkage will be lost and slippage can occur more easily. A properly machined fit, free from irregularities so that the shrinkage will be maintained, should be just rough enough to inhibit slippage.

To answer Mr. Stone's inquiry relative to the thickness of repair sleeves shrunk on the journals of two-high mill work rolls, we wish to state that this will vary greatly depending upon the design and size of the roll. It is hardly advisable to use a sleeve less than ½ in. thick. It should be remembered that these sleeves are fairly soft and can be assembled with a reasonably high shrinkage. The use of a reverse taper is also desirable. Some repairs have also included tack-welding of the sleeve to the roll neck adjacent to the wobbler.

Answering Mr. Smith's comments relative to the rolls which had the necks break off after resleeving, we submit the following: A cast mandrel which was to be sleeved fell apart in handling. It broke at the fillet and examination showed numerous circumferential cracks in this fillet, a number of which had progressed to considerable depth. Examination of the fillet on the neck which did not break showed a number of cracks which would escape all but the most rigorous examination. Such a condition probably existed on the rolls which Mr. Smith described. If such was the case, the fact that the roll happened to be a sleeve-type roll had nothing to do with the failure. A one-piece roll would also have failed.

Mandrels should be examined very carefully, particularly in the fillets, before they are shipped to the roll maker for sleeving. If a doubt exists as to whether a crack is present, the surface in question should be polished very carefully at right angles to the suspected crack. The area should then be etched with a 20 per cent aqueous solution of nitric acid and examined with a magnifying glass. This process should be repeated until the crack disappears or until it is useless to grind deeper. If the crack is eliminated, repolish to eliminate the etching pits which themselves might serve as nuclei for a detail failure. This also answers Mr. Hand's question.

Replying to Mr. Moses' question regarding the necessity of bores in hardened steel rolls, we wish to state they are necessary for the proper heat treatment of the roll and to insure against its breakage during hardening. Some of the smaller sizes do not require bores.

Deep freezing treatments are usually confined to austenitic steels having a depressed transformation point. Where full hardness has already been attained, little, if any, advantage can be expected from a deep freeze treatment. Such is the situation with respect to hardened steel rolls.

ENGINEERING

Postwar Industry

". . . . authority and responsibility go hand in hand, and they cannot be separated . . . . we cannot delegate authority and responsibility and have these functions controlled by outside leadership . . . . "

by Clifford F. Hood, PRESIDENT

AMERICAN STEEL AND WIRE COMPANY

CLEVELAND, OHIO

▲ AS I stand before you, I am wondering if you gentlemen are fully aware of the important part you are to take in helping not only this nation, but the entire world to overcome the effects of the epic struggle through which we have just passed.

We in the steel industry are fully aware of the contributions you have made in the past in developing more efficient and economical methods of producing iron and steel, and we realize that you and members of your fraternity were highly instrumental in enabling the steel industry to write such proud achievements in the record of production for war. The steel industry met all the demands of fabricators of war machines and equipment, and met those demands on time. I know of no instance where production of war goods was held up by failure of the steel industry to deliver material on time.

It was truly a gigantic task, but it was accomplished and the figures will speak for themselves. More than 300,000,000 tons of steel ingots and castings were produced during the war years for ultimate processing into practically every piece of equipment used in a modern war. Ships, guns, aircraft, tanks, helmets, ammunition, flame throwers, rockets, bulldozers, railway equipment, pipelines, wire ropes and cables, radio equipment — in short, every phase of our war effort was dependent upon steel in tremendous quantities, in a wide range of analyses, and in practically every conceivable shape.

To produce this almost fantastic quantity of steel, the industry spent $1,310,000,000 of its own money for war expansion, in addition to $1,095,000,000 expended by the government. In other words, the industry put out more actual cash in meeting the crisis with which we all were faced than the government did. I mention this merely to point out that our capitalistic economy was as willing to expend time, money and effort to combat oppression and barbarism as were the men charged with leading our nation away from the abyss of defeat and subjugation. The steel industry actually spent more money to provide facilities to combat our

Mr. Hood presented the accompanying talk at the Cleveland session of the annual meeting, October 3, 1945.

enemies than the industry's stockholders received in dividends during the 12-year period, 1931 through 1943.

In producing and expanding for war, the industry overcame seemingly insurmountable handicaps in the form of manpower shortages, procurement of equipment and raw materials, and transportation difficulties. In addition, we were required to abide by the regulations and directives issued by the various government agencies, to file literally thousands of reports, and to answer a virtual avalanche of questionnaires. I am not questioning the need or wisdom of these records and forms, but merely mention them to round out the picture of the difficulties under which we operated during the war emergency.

So now the war is won. Regulation of production and distribution has, for the most part, been abandoned. We are now proceeding with conversion to peace-time production, which, for the industry, will cost over $200,000,000. While we do not pretend to have all the answers, we do have an overall plan, one which can be adapted to most foreseeable contingencies. Unfortunately, we find that labor has only one idea in mind for the postwar period, and that is higher and higher wages, regardless of the effect on the entire American economic structure and the dangers of inflation which inevitably must follow.

All of you undoubtedly are familiar with the current demands of the United Steelworkers of America for a $2 per day increase in steel wages. It has been estimated that such an increase, if granted, would raise labor costs of the steel industry by $300,000,000 annually. This figure is more than 60 per cent greater than the $178,000,000 which the industry reported in net profits last year. It is a 32 per cent increase in the basic labor rate, and a 21 per cent increase in the average overall straight-time rate in United States Steel Corporation's steel producing facilities. Where is the money coming from?

Some of the spread between last year's profits and the cost of a $2 per day wage increase would be offset by decreased tax payments, but certainly not to the extent envisioned by the union and by no means in sufficient amount to make up the total difference. There is no means by which the total difference could be absorbed except by government subsidization at the expense of the taxpayers, or in higher selling prices of steel, at the expense of the consumers.

That is the outstanding flaw in the whole fabric of the union's demands. I want to emphasize that fact — that any increases in remuneration granted to the steelworkers are going to be paid by the American public if the steel companies are to avoid back-breaking deficits and eventual bankruptcy. The companies are physically unable to absorb any substantial increases in production costs. Composite prices of finished steel products already are frozen at levels below those existing in March, 1937, and almost without exception costs of materials and production have risen steadily with the result that the industry's very existence is threatened. Some sort of relief in the form of either lower production costs or higher steel prices is going to have to be given soon. Any additional financial burdens imposed upon the industry may have very serious and far-reaching effects upon our entire economy.

Costs and prices vary among steel products and producers, but on the average there has been a net change since 1940 of at least $7 to $8 per ton to the disadvantage of the steel producer. These costs were offset to some extent during the war period by the extraordinarily high rate of production and the tremendous volumes of single types of material, which permitted the operating economies attendant to long runs requiring no equipment adjustments or other time consuming activities. Even so, our costs were out of proportion to the average price we received for steel. However, at that time our most precious commodity was time, and the steel industry was concerned with only one problem — production at any cost in order that our fighting men might be adequately equipped for the job they had to do.

Now, however, with the return to more normal operations, we are faced with the disappearance of the advantages inherent in long-run operations. At the same time, with the desperate need of our armed forces satisfied, the day has arrived when steps should be taken to correct the unfavorable spread between production costs and selling prices. The sooner the realities of the situation are faced, the sooner we are going to get on with the job of rebuilding our civilization.

The demands of the steelworkers, however, are only

one phase of the problem, a phase which, when taken by itself and compared with over-all consequences, is relatively insignificant. If the steelworkers were granted their sharp increase in wage rates, it will merely be the firing of the gun signaling the start of another lap in the race between living costs and income. Upward revision of the current standards of pay will almost automatically insure a like action to the questionable benefit of workers in all industries. That would do more to jump living costs above their present levels than any other single thing I can imagine. In all manufacturing operations, labor, next to raw materials purchases, is the largest single item in production costs. The minute a manufacturer has his labor costs revised upward, the selling price of his product has to be adjusted accordingly. I am certain that no responsible individual in industry, including myself, has any desire to keep the wages of the workers in the mills and factories of this country at a depressed level merely for the satisfaction of depriving the workers of a better way of life. That is not the method by which vast, mass-consuming markets are built up. It definitely is to the advantage of every one of us to have the income of the working man continue to increase as it has in the past. I hope to see the day when the steelworker and every other American workman can increase his earnings much more than the 25 cents per hour now demanded.

What is too often overlooked by those demanding higher wages for the working man is the fact that a fat pay envelope does not necessarily mean more wealth. What is the difference if a man has his income doubled, or if the cost of living is halved? In the former instance everything he buys will increase in price by 100 per cent or more, while in the latter case, while the paycheck may be smaller, he will still be able to buy as much as, or more than, previously. What should be of primary importance is the "economic wage," or the relationship between what a man earns and what he can buy with those earnings. Money, in the final analysis, is merely a medium of exchange. It has no intrinsic value of itself. It is only for what it will buy that everyone wants to earn more money.

A few years back the American Iron and Steel Institute made annual comparisons of the purchasing power of the income of steelworkers in America, Great Britain, France, Germany, and other foreign countries. Needless to say, the American's paycheck was, in every instance, larger than that of his foreign brother. What is even more important is the fact that the commodities which that paycheck would buy exceeded the possible purchases of the other workers to a greater degree than was reflected in the paycheck itself. In other words, not only was the American's dollar wage higher, but his economic wage was greater still.

It is the economic wage of the workers with which our labor leaders should be concerned. Merely adding $2 a day to each steelworker's pay envelope is not going to increase his purchasing power one bit. But if that $2 daily addition reflects increased production and lower unit costs, it is a real rather than an illusory gain because the selling price of steel can remain unchanged, or possibly be lowered, and the things the steelworker buys with his dollars will remain at a level which will not consume all his increased earnings.

Under present methods of production, however, it just is not possible to increase costs sharply without passing the bill on to the consumer. While future developments and improvements undoubtedly will add to the individual worker's productivity, at the present time wage rates are at such a high level that immediate price relief is necessary if operating deficits are to be avoided.

During the period in which we were producing for war, prices of products were of secondary importance to our armed services. As I mentioned earlier, we were interested only in production at any cost. If it was necessary to pay premium overtime wages for maximum output, it was accepted as one of the penalties of producing for war, and the ability of the United States government to pay was never questioned. In spite of the unprecedented sales volumes in the steel industry, net income on investment during the war years averaged less than 6 per cent, while in relation to total sales, the net return was considerably less. I mention this merely to combat accusations that the industry benefited from war-swollen profits.

The resources of our single war-time customer were seemingly limitless. The mightiest and wealthiest nation on earth, by tapping every source of income, was able to meet the staggering war bills which totaled hundreds of billions. However, in so doing, our government merely deferred actual payment for many years to come. The huge national debt with which we are saddled is going to take years to service and amortize. The resources of the entire American public are going to have to be partially devoted all during our lifetime to helping our nation honorably meet its war debts. That is part of the price we must pay for the inflated costs of materials of war which necessarily had to be paid.

In a civilian market, on the other hand, the ability of the consuming public to put out the sums of money to buy things to satisfy its needs and desires definitely is limited, and once the price of a product rises above a certain point, purchases of that item start to fall off or cease altogether. That is the one thing that labor must keep in mind; the only reason we have built up our mass markets is that we have constantly lowered the prices of the goods the consuming public wants and buys.

My economics may be a bit old-fashioned when measured by some of the more modern standards, but my common sense, if nothing else, says that markets are not created by paying premium wages to a portion of our population for a moderate amount of production, with the hope that those premium wages will of themselves produce greater purchasing power. Only by keeping costs and selling prices at an absolute minimum can you sell larger and larger quantities of goods, the manufacture of which requires more and more workers earning higher and higher wages, and thus create more and more potential customers. To declare that any other method will produce the result we are all after is putting the cart before the horse and, to my way of thinking, is just plain silly.

As we all know, the war through which we have just passed was the most widespread and destructive in the history of mankind. Not only have millions of lives

been sacrificed, but countless billions of dollars worth of property has been destroyed and inestimable portions of our natural resources have been dissipated. The tragic loss of the cream of our manhood is something which never can be overcome. Our natural reaction to the death and disabling of this nation's young men is to think of the shattered homes, the heavy hearts, and the added burdens which wives and mothers of the injured will have to bear. What is frequently overlooked is the loss involved to humanity in general. Economically, the penalty for the obliteration of hundreds of thousands of young men's lives will be paid many years hence. We have no way of knowing how many potential Edisons, Steinmetz's, Gershwins, Shakespeares, or Ketterings may have fallen on the field of battle. We do know that many thousands of the young men upon whom the future progress of this country and the welfare of our children rely have been irretrievably lost in the maelstrom of war. The very attributes which they could have devoted to improving our way of life in the years ahead led them to victory, and — in too many cases — to death.

The reconstruction of ruined cities and rural areas presents a titanic job to be done. However, buildings and industrial installations can be replaced, and farmlands can again be made fruitful and capable of providing foodstuffs.

Aside from the human loss, what are more serious are the disruptions and dislocations of entire economic systems, the uprooting of civilizations, the interruption of established methods and practices not only of carrying on business but in personal day-to-day relationships. No war has been waged in modern history without creating these strains and stresses which take years to relieve. When the distortions in the various component members of our world structure are eventually eliminated, we shall find that we are not returning to the same established practices and customs with which we were so well acquainted previously. The basic foundation may be pretty much the same, but we will find that the structure has been strengthened and buttressed at various points, while certain bottlenecks and inefficiencies have been eliminated, only to be replaced by new ones. There will be some alterations in the way of population shifts and newly created industrial areas which will be permitted to remain and be incorporated into the whole.

Fundamentally, though, the basis upon which our civilization has been erected will have to remain unchanged if we are to continue to progress and make a better world out of the chaos which has befallen us. That basis is plain hard work. This nation was built up to its present preeminent position by dint of hard work. When the Pilgrims first landed at Plymouth in 1620, they had no choice but to roll up their sleeves and set themselves to the grim task of providing food and shelter for themselves and their families. They observed no set hours of labor and their only payment was in their hearts, in the knowledge that they were providing some small measure of security for themselves. The only rule which they had to guide them in their daily tasks was: "He who does not work, does not eat."

In due time they strengthened their foothold on the new continent and established themselves as an enduring community. In the ensuing years, other rugged pioneers by sheer strength and hard work forged farther inland and threw back the physical barriers to civilization.

With the coming of the industrial revolution, other hardy individuals laid the steel ribbons across the wilderness which converted a series of scattered communities into a closely knit nation which was destined to assume leadership of the world. Hard work brought into being iron and steel mills, implement manufacturing plants, textile mills and all the various types of industrial establishments which go into the making of a mighty industrial nation. Night and day, over a period of years, men worked and sweated in the mills and factories to build industrial America. Hard work was accepted to be the manner by which such a huge project could be completed. There was no substitute for work and none was sought. There was a job to be done, and if hard work could do it, that job would be done.

The only method by which the job we are now facing can be accomplished is by hard work, the same as all big projects have become reality in the past. I do not by any means maintain that we shall have to revert to a 10- or 12-hour working day when all daylight hours are spent on the job. That has been proven to be not only undesirable from an individual's point of view, but inefficient from a productive standpoint. I do say, however, that with a tremendous national debt to be amortized and extremely serious adjustments to be made in our way of life, we must assume a realistic outlook of the problems at hand. I cannot agree with those Pollyanna theorists who forecast a milk and honey existence now that the frightful business of war has ceased. The mere fact that tremendous backlogs exist in the demand for a multitude of articles necessary to our daily existence does not necessarily assure that money in almost limitless amounts is going to be available to satisfy all of our wants or even all of our needs.

The highway ahead of all of us should be clear. If that highway is to lead away from chaos and eventually bring us to an era of peaceful and prosperous existence, it will behoove every segment of our national life to pave that highway with bricks created out of clear and realistic thinking and industrious application to our daily tasks. More than that, those bricks will have to be bound together by the mortar of mutual trust and friendship. Every phase of our industrial, economic and social life will have to make its full contribution to the welfare of the nation as a whole.

There probably is no more important a group of individuals in this whole picture than that of which you gentlemen are members. As I mentioned at the outset, I wonder if you are fully aware of the importance of the task which it is going to be your lot to perform. Dr. Vannevar Bush, director of the Office of Scientific Research and Development, has written that one of his hopes is that after the war there will be full employment, and that the production of goods and services will serve to raise our standard of living. He states that it is not known yet how we shall reach that goal, but it is certain that it can be achieved only by releasing full creative and productive energies of the American people.

"Surely we will not get there by standing still," Dr. Bush states, "merely by making the same things we made before and selling them at the same or higher

prices. We will not get ahead in international trade unless we offer new and more attractive and cheaper products."

He further asserts that there must be a stream of new scientific knowledge to turn the wheels of private and public enterprise.

I do not think there can be any disagreement with those sentiments by any thinking person who stops to realize that the high standard of living which prevails in our country today is made possible only through the development of newer and better products, together with speedier and more efficient methods of turning out those products. The very same formula is going to have to be followed in the days to come if we are to continue to progress and retain our leadership.

Principally through the development and research activities of our engineers are we going to realize that better way of life which we all can see in the future. And it is particularly true of this group, inasmuch as this still is a world of iron and steel in spite of the creation and development of newer materials which hope to compete with steel. There is no doubt but what the plastics and lighter metals can find a useful place in the world of the future, but there also is no doubt but what iron and steel will continue their dominant place as the backbone of our civilization. For that reason I say that this group, more than any other similar organization, is going to be charged with the major part of the burden in developing a more progressive way of life.

I mentioned earlier that it was utterly impossible for the steel industry to increase its labor costs without passing the bill on to the consumer. However, I qualified that statement by saying that that was true under present methods of production. That is the crux of the whole question.

As more efficient and time-saving methods of production are introduced, labor costs per unit will go down. Only through such means can we successfully increase our economic wage without raising our selling prices and endangering our consumers market.

It is the engineers upon whom we must call to bring forth those improvements which will permit the working man to produce more within a given length of time. Machines and techniques, however, are merely a means to an end. No machine yet devised can perform an entire operation by itself. The most important element in our production remains what it always has been — the human being. Only men can control equipment and machinery and make it do what it was designed to accomplish. Only men can organize the machine's productivity and obtain top performance. It is here, again, that you gentlemen have a responsibility, because your jobs in many cases are primarily concerned with the men who operate the machines rather than with the machines, themselves. This brings us to the problems of management and organization and the many pressing questions of the moment.

You men have a great deal to do with management as well as engineering, and among one of the most important phases of management with which we have recently become familiar is the matter of unionization of foremen. When industry is faced with the threat of having a large segment of management organized, it is time to meet that situation with clear thinking and determined action.

It has been through free, unhampered management that American industry has built the industrial empire with which we are familiar. It is the beginning of the end if management tries to go east and west at the same time. Authority and responsibility go hand in hand, and they cannot be separated. We cannot delegate authority and responsibility and have these functions controlled by outside leadership.

You well know that oil and water do not mix. Neither do unionization and management mix. To the extent to which such conditions may occur, a revised form of supervision is indicated.

It is believed that management's best approach to this situation is to meet the situation frankly and directly through discussion with those men who are or who may be interested.

We in our organization have followed such a procedure. You will recall that the National Labor Relations Board, in a majority opinion, has stated that foremen are nothing but traffic cops. We do not believe that these foremen want to be traffic cops.

Company policy, if it is not already established, should be established to the effect of recognizing individual initiative, of recognizing individual ability, and of recognizing individual capacity to assume leadership.

We like to think of management as a team in which each player has his part to play and plays it well, and in so doing contributes not only to the well-being of the team as a whole, but makes the maximum contribution toward his own individual effort and toward his own individual advancement.

One of the arguments which is so frequently advanced as being a keystone as to why men in management should seek organization is that they will have greater security. At that point I think we ought to pause and ask "What is security? How is it obtained? How do we go about it?"

Certainly it is not obtained by someone signing his name on a piece of paper. It seems that the best guarantee of security, not only for those engaged in management and in supervision but also for those who work with their hands as well as their heads, is to build a strong company which has good organization, a company which is strong in good productive facilities, a company which is strong financially, and a company which has the ability to satisfy its customers.

It is the prerogative and the duty of management to oppose aggressively, by all proper and legal means, the organization of our supervisory forces for the purpose of unionized collective bargaining, and in that particular endeavor industry has this matter squarely in its own hands. It is a challenge which must be met, and met squarely and fairly.

You men and your predecessors have done a magnificent job in the past in lightening the burden of mass production and you are to be further charged with the responsibility of relentlessly pursuing more and more efficient production techniques to the end that higher wages can be paid, more goods can be produced and the standard of living of our whole nation can be brought up to the level which will permit every individual to live graciously and enjoy the simple pleasures which are the right and heritage of all mankind.

Overload Protection FOR MILL-TYPE D-C Auxiliary Motors

. . . . what to do when the motor overloads has always been a bone of contention between steel mill maintenance men and operating men . . . . this paper discusses in detail the operation of several types of overload relays and their application, particularly to mill-type motors . . . .

by G. A. Moffett

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SCHENECTADY, NEW YORK

▲ BEFORE discussing the protection of d-c auxiliary motors, it is, I believe, advisable to arrive at a common understanding on the meaning of the term "overload" and to briefly review the characteristics of the motor we are attempting to protect. To arrive at this common understanding it is necessary that we recognize and differentiate between overcurrent, overtorque, and overload. Overcurrent implies a current condition more severe than that of a stalled motor or maximum commutating ability, in other words, a short circuit; overtorque — a condition of loading that would cause a motor to stall or to draw a current in excess of its safe commutating ability; and overload — as a continuous or rms current condition within stalled or commutating ability but above nominal or the 100 per cent current rating.

A motor when operating within its mechanical and commutating limits has only one reaction other than attempting to produce a rotating torque to the current passed through its windings, namely, the generation of heat. Starting with a cold motor, if the current is continuous and nominal, the heat will be generated gradually, will pass from the copper of the windings through the insulation to the iron of the machine, resulting in a gradual rise in temperature of the copper, insulation and iron, and will level off at the machine's allowable temperature rise, which is usually recognized as 75 C. If on the other hand the current is in excess of nominal, the heat is generated at a higher rate, and as the rate increases it becomes more difficult to conduct this heat through the insulation to the iron, and we ultimately reach a condition when the insulation will be at a higher temperature than its allowable rise. Such a condition will not result in an immediate motor failure; it will, however, cause an increase in rate of insulation deterioration which simply means a shorter life. As a rule of thumb, we are told that the insulation life is halved for every ten degrees of excess temperature for the length of time of maintenance of that temperature, and, conversely, the insulation life is doubled for every ten degrees under the allowable value for the length of time of maintenance of this temperature.

When we use the term horsepower in connection with a mill-type motor, practice and usage have caused us to refer to its one hour rating. The terms starting torque, running torque, service factor, ½ hour and even ¼ hour

Presented before A. I. S. E. Pittsburgh District Section Meeting, January 8, 1945.

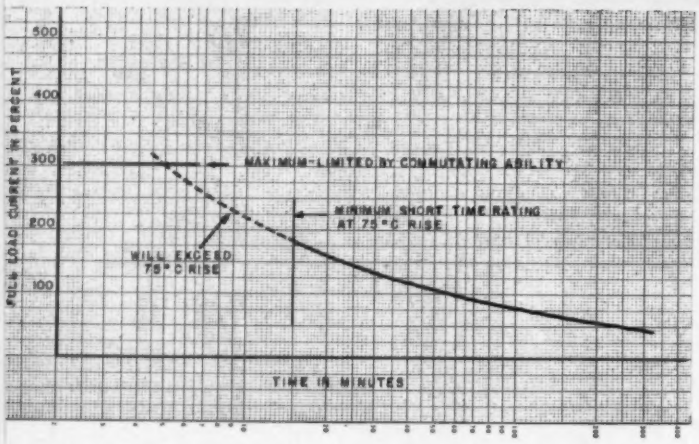


Figure 1 — Time-current characteristics for A. I. S. E. No. 12, 50 hp motor.

ratings are familiar. What do these terms mean and how are they arrived at? First of all, they refer to some base — again the 1 hour rating. In a compound-wound mill-type motor the established ratio of starting torque to the 60 minute rating torque is 4½ and the maximum running torque to the 60 minute running torque is 3½ to 1. Starting torque ratings are limited only by mechanical construction, and running torque by commutating ability. Service factor, ½ hour, ¼ hour, or any other horsepower rating, together with the frequencies of the torque ratings, are established, however, solely from temperature considerations.

These temperature limitations result in a motor characteristic following the pattern of the A. I. S. E. No. 12 50 hp, 1 hour motor, which is used as an example and is as follows:

Hp	% Hp	Full Load Amp at 230 v	% Full Load Amp
22½	45	83	45
50	100	185	100
65	130	245	132
90	180	350	190

This published data is not sufficient to complete the thermal characteristic. We know, however, that the safe commutating or running torque is 350 per cent of the 60 minute rating, and assuming that such a point can be held for 4 or 5 minutes without exceeding a prohibitive rise, we may add very important points to our curves which give us more complete characteristics. Such points would be:

Hp	% Hp	Full Load Amp at 230 v	% Full Load Amp
133	265	560	305

The characteristic current time curve thus obtained would be as indicated in Figure 1.

If we are to accept all of these as fundamental factors, then we must think in terms of temperature when we think of overload protection.

The mere fact that a relay operates on a temperature principle does not mean that it provides overload protection. A motor has, as was demonstrated above, a definite and well defined heating characteristic, and if we are to provide overload protection in accordance with our definition, we must have available a relay whose characteristic matches that of the motor.

Two types of relays are commonly used today to give protection to our motors. You are to note that I have used the term "protection" because in present day practice overload protection in the true sense of our definition is not used. These two types of relays are "instantaneous" and "inverse time."

The instantaneous relay consists essentially of a series coil, a magnetic plunger, and a contact assembly which may be of the automatic or hand-reset type. This relay, as the name implies, will operate instantaneously when the current in the coil (motor current) reaches or exceeds the pre-determined value at which the relay is set. Such a relay is usually chosen with a coil of a current rating in excess of the 60 minute motor rating and having a calibrating or setting range of from 200 to 400 per cent of this 60 minute rating. If we are to take advantage of our maximum running torque — and we do — we must set the relay at approximately 350 per cent. With such a relay and setting, two conditions become obvious:

1. We cannot take full advantage of the 450 per cent maximum starting torque as the relay must be set to protect the 350 per cent running torque.
2. A relay with such setting definitely offers no thermal protection.

The inverse time relay, like the instantaneous type, consists of a coil, a magnetic plunger, a contact mechan-

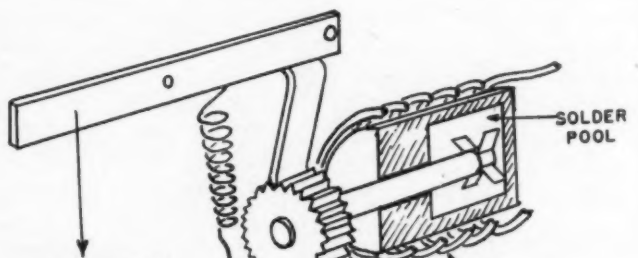
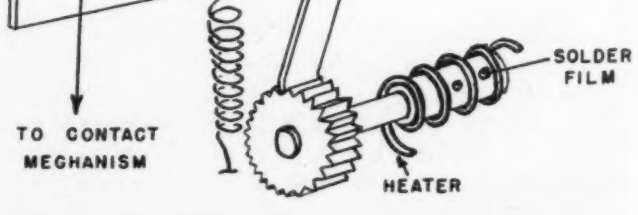


Figure 2 — Solder-pot or low temperature solder thermal relay.

▲

Figure 3 — Solder-film type of thermal relay.



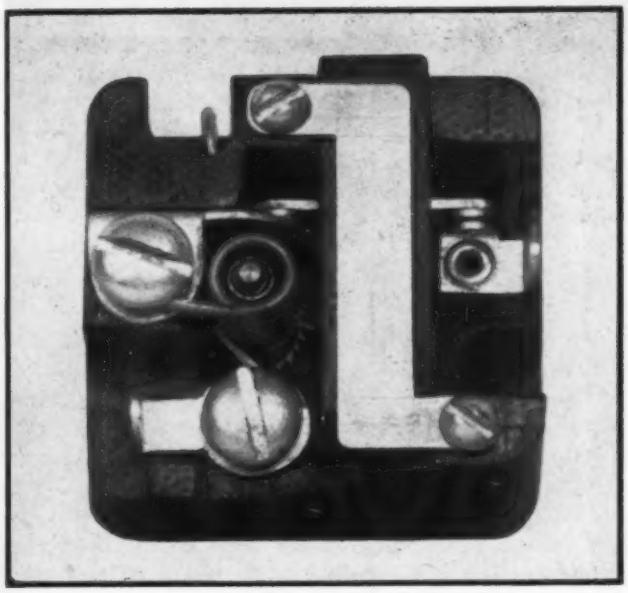


Figure 4 — Photograph of solder-film type of relay.

ism, and in addition some restraining means attached to the plunger which gives a purposely delayed action. The time delay, as the name implies, is inversely proportional to the current flow in the relay coil.

Such a relay is usually chosen with a coil giving a time adjustment range of from 100 to 250 or 300 per cent, with a corresponding instantaneous range of from 250 to 500 per cent. With such a relay set at minimum and with full running torque applied, the relay would operate instantaneously. On the other hand, if the relay was set at maximum and maximum running torque applied, the relay would trip in approximately 30 seconds. With the same relay settings and minimum running torques within the tripping range, we could expect a maximum timing of approximately 100 seconds. There are, of course, different makes of this type of relay available, and the calibrating and timing ranges will vary. They all, however, follow essentially the same pattern, and when it is compared with the time allowed by the motor's thermal characteristic it becomes quite obvious that this relay will provide a degree of overload protection for a continuously loaded motor, but for one having a wide and variable duty cycle, it offers little more than that of the instantaneous relay. It does not permit full use of maximum torque nor does it give thermal protection. Therefore the only advantage of the inverse time over the instantaneous relay for a mill auxiliary is that it may be set at a lower value of current.

This is the kind of protection we are giving the mill type motor today. It is the same protection we were providing 15 to 20 years ago. The need for more adequate overload protection is becoming more evident and is actually a matter of growing concern to many maintenance men. That there should be thousands of mill type motors operating without any effective overload protection for the motor itself may be surprising to many; yet such is actually the case. While many people are looking for more adequate overload protection, a large group still feel that the instantaneous relay is entirely adequate. This group feels that good maintenance is the best insurance against overloading and the consequent overheating of the motor. In fact, good maintenance is today the only practical insurance against destructive overheating of the mill motor and as such the degree of freedom enjoyed from motor burnouts is a tribute to both the quality of maintenance and to the sturdiness of the mill type motor.

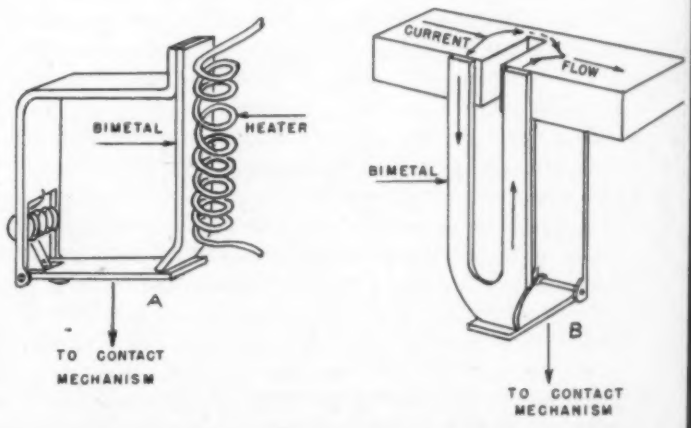
Is present practice sufficient? We fully appreciate that the duty cycle imposed on the mill motor is variable and is most severe. We appreciate that the mill motor is of unusual sturdy construction and as such is well adapted to this type of application. We also fully appreciate that these motors are very carefully selected for their specific jobs — and they do them well, as long as conditions are normal. Occasionally, however, conditions become abnormal and when these abnormal conditions arise, we must rely on the skill and training of electrical maintenance personnel for protection.

What kind of protection should be provided? We have attempted to find the answer to this question, and get many answers which can be roughly classified in four groups.

1. Some mill men have informed us that there should be no protection.
2. A large group feel that the protection offered by the instantaneous relay is sufficient.
3. A third group appear to be in favor of an inverse time relay.
4. Others feel that thermal protection should be provided.

If we are to consider the thermal relay, it is advisable to give consideration to the physical construction and the characteristics which these relays provide. The thermal relay consists essentially of three parts — a heat producing means, a heat responsive means, and a contact mechanism. The heat producing means for d-c

Figure 5 — Bimetal heater type thermal relays. The line current generates heat which causes the bimetal to deflect away from the end of the latch. When the bimetal has deflected enough to release the latch, the latch moves upward, actuating the contact mechanism.



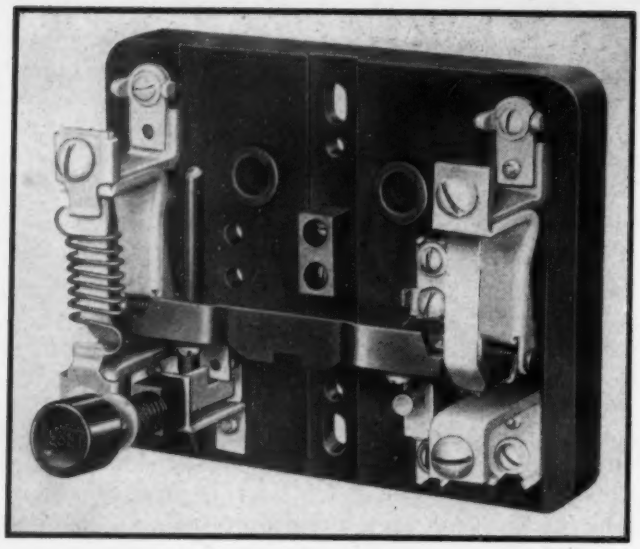
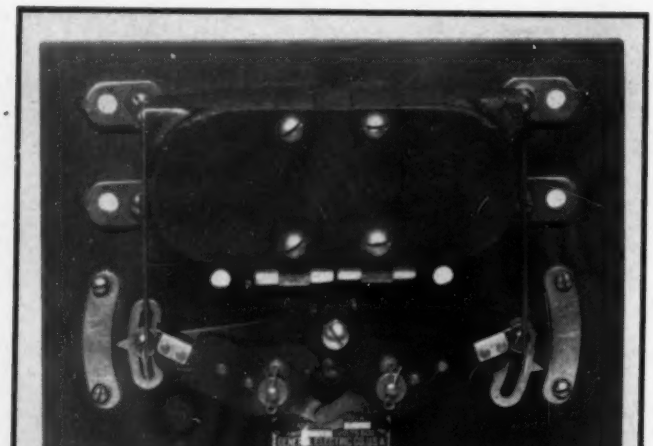


Figure 6 — Photograph of bimetal thermal relay illustrated in Figure 5A.

▲

Figure 7 — Photograph of bimetal thermal relay illustrated in Figure 5B.



operation would be restricted to those of the resistance-type in which full or partial motor current is carried through a heater whose temperature is increased by motor current and this heat radiated or conducted to the heat responsive mechanism. The heat responsive mechanisms can be divided into three common groups — low-temperature solder, bimetal, and expansion metal types.

The low-temperature solder type, commonly known as "solder-pot" or solder film, is illustrated in Figure 2. The solder-pot relay usually consists of a container filled with a specific amount of low-temperature solder, forming a stationary member, and in addition a movable member consisting of a ratchet or gear having an irregularly shaped stem that is inserted in the pot or pool of solder. The gear is used for applying a force necessary to rotate or move this member, thereby actuating a set of contacts when the temperature of the solder has been raised to its flow point. For proper and consistent operation of this type of relay, it is necessary to maintain accurately the melting point and amount of solder used. It is also necessary to keep the exposed surfaces to a minimum and to keep the parts absolutely clean during assembly. Otherwise oxidation of the solder or the parts will seriously affect the operation and characteristics of the relay.

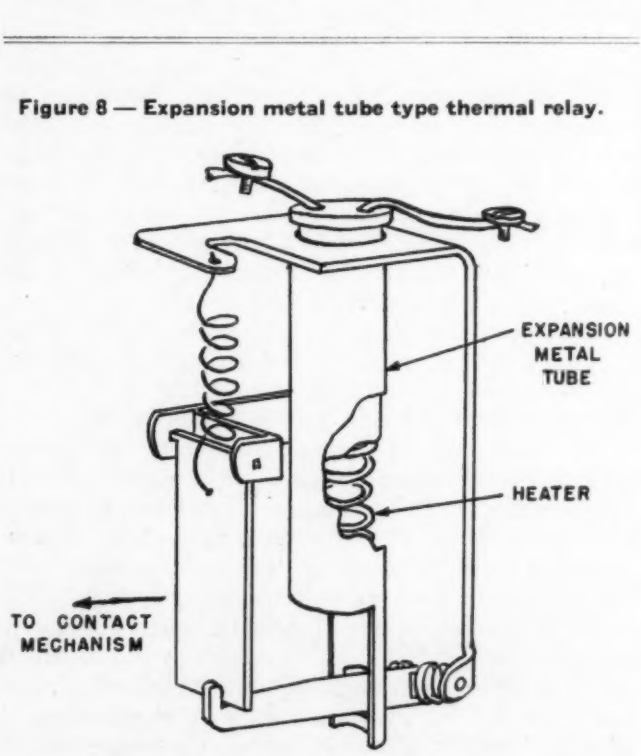
The solder film, shown in Figure 3 and Figure 4 is essentially the same as the solder-pot except that it does not use a pool of solder but a very thin film of solder between the stationary and movable parts. In this design, a very small amount of solder is used and as such reduces possible difficulties, such as slagging and loss of solder from irregular mounting.

The bimetal types of thermal relay are the most common type used today and have been manufactured for a great number of years with good success. There is available to the relay designer a large variety of bimetals, both with respect to thermal characteristics and physical shapes, which give a wide latitude in choice of metals to meet the particular requirement for a specific form of relay. In all cases the bimetal element operates some form of contact mechanism which is subject to friction variation, and as such the bimetal element must have an ample power margin; otherwise erratic operation may result from variation in the mechanism proper. It is also essential that the bimetal be normalized by heat treatment after forming operations to eliminate the possibility of permanent change with aging in relay calibration.

A large variety of bimetal relays are available; the most common types use the bimetal as a cantilever, disk, and helix. Both the cantilever and the disk give a straight-line motion to the associated mechanism, while the helix operates by rotary motion. Common forms of the cantilever type of bimetal mechanism are as illustrated in Figures 5, 6, and 7.

Expansion metal relays are relatively rare. These

Figure 8 — Expansion metal tube type thermal relay.



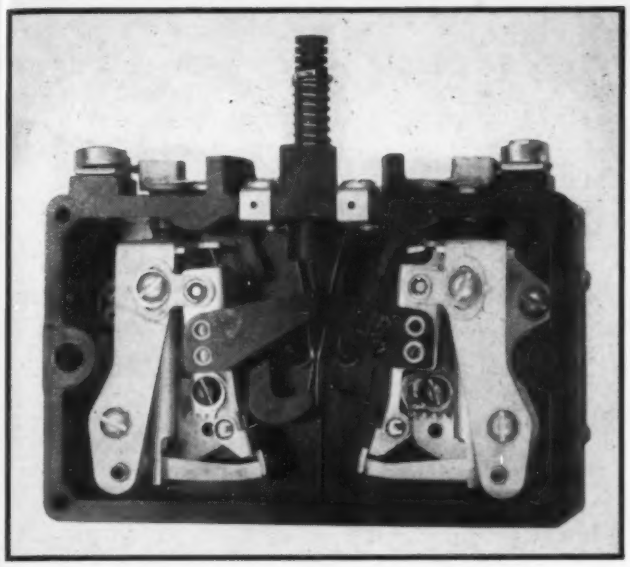


Figure 9 — Photograph of expansion metal tube type thermal relay.

consist of essentially two types, the so-called hot-wire and expansion-tube relays. So far, the hot-wire type of relay has not proven too successful due primarily to the physical size required to accommodate the length of wire necessary to make such a relay operative.

There has, however, recently appeared on the market an expansion tube type of relay which is of acceptable physical size for relay usage.

The temperature responsive element of this relay consists essentially of a supporting frame, a manganese alloy tube, and a lever mechanism to actuate the relay contacts. A heater is inserted in the tube which on the application of heat causes the tube to elongate and in so doing releases the latch mechanism, which in turn operates the relay contacts. As the elongation of the alloy tube is very small, a large multiplication of lever ratios in the latch mechanism must be used, and as such it is very essential that the parts be held to very close tolerances. As the heater is completely surrounded by the alloy tube, the heat transfer from the heater to the tube is very efficient. Relays of this type are as illustrated in Figures 8 and 9.

Relays of the thermal type are used quite successfully and almost universally on squirrel-cage induction motors whose characteristics are variable and, I believe, harder to match than those of the mill-type motor. It appears, therefore, that it is not an impossible task to provide a thermal relay to match the thermal characteristic of the mill motor.

In considering the thermal relay we must remember that it heats and cools in a manner similar to that of the motor, and as such once the relay has operated it is not suitable for instantaneous reset. The resetting time can, however, be controlled and reduced to a value that is a fraction of the tripping time. The questions then arise as to whether reset time is permissible on a mill auxiliary or whether instantaneous reset is required? If time is allowable, then what is the maximum permitted? These are very important questions to the mill operator and relay designer, for if thermal protection is to be considered, there must be agreement on these points.

In attempting to answer these questions, it is obvious that we cannot reflect the true picture of motor heating and cooling in a relay unless we allow the relay to cool and reset in a time which is comparable to the cooling period of the motor. A shorter reset time, therefore, represents a compromise which we must accept in order to make the application practical. It then becomes a question of "degree of compromise," the greatest degree being that of instantaneous reset.

I have attempted to give a few of the limitations and characteristics of motors and of relays. It is hoped that these remarks will promote thinking and discussion on the part of the user, from which may come the answer to the question, "What type of protection should be provided?"

DISCUSSION

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J. W. STIRLING, Manager Protective Devices Section, Application Department, Westinghouse Electric Corporation, East Pittsburgh, Pennsylvania

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M. W. SMITH, Project Engineer, Pittsburgh, Pennsylvania

J. S. MURRAY, District Manager, Alliance Machine Company, Pittsburgh, Pennsylvania

G. A. MOFFETT, General Electric Company, Industrial Control Engineering Division, Schenectady, New York

G. E. Stoltz: I suppose there is no class of motor today in the steel industry that receives more abuse than

the mill type motor. I do think we have come to the place where we have a pretty fair knowledge of what the application requirements are and can select a motor that will not necessarily be overloaded. There has been a great accumulation of information from the time when we had to guess at the power requirements. The bearing design used on the machinery that the old motors drove was poor, and sometimes the motors were required to operate these drives with bearings having very little lubrication. In the older days the gearing was not nearly as good, so it was quite difficult to properly select a motor to meet the conditions that might prevail. Today machinery is well designed so that there is not much variation in motor loads.

Mr. Moffett mentioned three different types of overloads. One is the torque overload. We do not ordinarily give this much thought or attention but an installation came to my mind that illustrates his point very well. I remember a hot strip mill where mill type motors are used on the screwdown. The screws are run down until the motors stall and when it is time to raise the screws, it is sometimes a problem to get the motors started. So we do have such applications as Mr. Moffett mentions where there is a definite torque overload.

Many of our old machinery applications should be protected by thermal relays. I believe the greatest trouble in the past with mill type motors has been overheating from one cause or another. To properly protect such applications I would use a thermal relay that would come as close as possible to the thermal time constant of the motor.

Some years ago we applied a meter that indicated the rms current of reversing blooming mill motors. This meter was lagged to have the same thermal time constant as the motor. It merely indicated the thermal condition of the motor at any particular instant.

I would also put on such a motor a relay to protect the commutator. It would protect against peaks of short duration, that would burn the brushes and the commutator.

Mr. Moffett has mentioned the time delay incurred for resetting the thermal relay without giving us the answer. He apparently feels the operators should express their views on this subject. In general the electrical department wants the motor removed from the line when it reaches a dangerous temperature while the particular operating department involved prefer to have the motor continue operation. The operating departments object to having the motor disconnected from its power source and in some cases they will make an alarm circuit ineffective.

In my opinion there is one of two decisions to make. The first is that the load conditions have been carefully studied and the electrical apparatus properly applied so that there is so little chance of overheating the motor, that thermal overload protection is not warranted. The second is an application where the motor may be subject to abuse from the operator or the driven machinery may be neglected and the bearings or other parts may produce increased loads that will overheat the motor.

On this second type of application I think the motor should be provided with thermal protection that removes it from the line when a hazardous temperature is attained. Some inconvenience will be incurred by the delay to allow the thermal relay to reset, but such interruptions should not be allowed to continue. With availability of present day, well designed machinery, and ready means of testing the load requirements, the cause of any repeated interruption of service due to overheating a motor, should be removed. If overheating is due to abuse from the operator the best way to correct this is to have a period of interruption of service each time the motor is overheated.

When reversing blooming mills were first installed the reset button for the main air circuit breaker between the d-c generator and the reversing motor was placed in the operator's pulpit. This made it possible for the operator to quickly reset the breaker. With such a convenient arrangement it was found that the equipment was subject to sufficient overloads to trip the breaker as many as twenty-five times a day.

It was finally decided to put the reset button on the breaker panel in the motor room so that the roller was required to advise the motor room attendant, and then wait for him to reset the breaker. It was immediately found that the roller adjusted his rolling schedule to not trip the breaker at the most but three or four times per day.

We as manufacturers then started a program of the development of relays to limit the current peaks so that the roller could throw his master switch from one extreme position to the opposite extreme position without causing the armature current to exceed predetermined safe values.

At the present time reversing mill control is developed to a point where the roller operates almost as he chooses, the current control limits the armature current to a safe value, and the circuit breaker is seldom tripped. As a matter of fact, reversing mill applications have been worked out so well that it is no longer practice to provide either thermal protection or indication. This method of correcting an improper, or inadequately controlled application is more logical than to be satisfied with an installation that is bound to continue to be troublesome.

There is a third type of application where overheating of the motor might only be occasioned by an emergency where it would be hazardous to remove the motor from service. Such an installation might best be served by the use of an indicating thermal demand meter that could be used by the operator to know the thermal condition of the motor.

R. E. Brown: Mr. Moffett did not refer to the type of overcurrent or thermal relay which is combined with a magnetic trip which one manufacturer introduced, and I believe several are now used with considerable success. That relay has been found to overcome some of the disadvantages of the straight thermal type.

I would like to hear the operating men express their views on the three kinds, the straight thermal, the straight magnetic, and the combined thermal and magnetic.

L. R. Milburn: A-c motors have been and are still being controlled with thermal overloads. The d-c mill motors, however, have not been.

I am familiar with one case in which two 45 hp mill type motors — working on a mill screwdown in parallel

— pulled sufficient current, in the stall position, to be equivalent to 450 hp for each motor. Had there been thermal overloads on these motors, I believe that we would have saved the destruction of the worm wheels. The ordinary overload will not limit the amount of current which a mill type motor will take.

It is my opinion that the only people who can help us to help ourselves are the control builders, and I think the electrical manufacturers are on the right track when they propose to design proper thermal overload protecting devices for mill type motors.

The question of time for resetting, when the overload device trips, is not so very vital.

When a d-c motor is protected by thermal overload devices and the overload trips, I am of the opinion that the piece of equipment should be investigated in order to relieve this overload.

I am inclined to believe that we should have automatic resetting inasmuch as the controls are generally removed from the motors at some distance, and are manually reset. Considerable lost time to reset the relays sometimes occurs.

F. Mohler: It seems to me that one of the fundamentals of this Association is to lay down the requirements of the steel industry, and I would like to see a subcommittee of the Control Committee formed to say what the steel industry wants. Now, whether the supply industry can meet your requirements or not remains to be seen. However, every time a relay is designed it costs $50,000, and one way or another, the steel industry pays for it.

J. D. Brick: I think Mr. Mohler is right as far as electrical manufacturers are concerned, because there is no universal relay. We have built thermal expansion hot wire and bimetal relays, and magnetic dash pot and noncreeping dash pot relays, but we have been unable to apply a universal relay for all applications that will satisfy all customers.

I agree again with Mr. Mohler that we can design and build anything the steel industry wants. With reference to the reset time of overload relays, there is no sense in trying to restart a motor immediately after it trips out, because it has reached its maximum thermal capacity; the motor is filled with heat, and why try to put in more when it is already filled to capacity? For this reason, there is no point in saying, "Well, we are going to have an instantaneous reset on a relay, particularly if it is of the thermal type." On the old dash pot relays you could apply instantaneous reset, because the relay tripped before the heat capacity of the motor was reached.

F. Mohler: There is one suggestion I have been mulling over in my mind on this reset problem. Even though you say, "O. K., let's take our time to reset," I know the first time you stick a slab in the mill, you are going to throw long time reset relays out. I have thought maybe the thing to do is to put in instantaneous relays for your short circuit protection, as well as thermal. However, the only thing the thermal would do would be to sound a horn every time it goes out, and let it blow until somebody does something about it. This method would at least allow the operator to finish out his slab.

L. R. Milburn: Don't you think what you are trying to prevent is the burnout of the motor? Your mill motor is built to take pretty nearly anything that comes within reason up to the stalling point. In fact, we do stall, and the motors don't burn out unless you leave them on too long. So the thermal overload would be all right, even if it took you an hour to reset it, because by the time you stalled the motor and tripped your overload relay, there would be something wrong with your machine.

C. B. Hathaway: It seems to me the question of protection is the value you save in the motor as compared against the loss in the product if you interrupt the service.

You find two kinds of applications where you need overload protection. One is where a machine is remotely located and the other is where it operates in the midst of attendants.

In the first case the motor should be cut off the line when it is overloaded to prevent a much longer interruption in service if the motor failed.

The second case is the common condition found in steel mills. As Mr. Moffett pointed out, one may assume that the motor has been applied intelligently; therefore, the trouble is not likely to be caused by excessive load from the driven apparatus, but because something has happened to increase the friction in the system. Now if the overload relay operates a signal, the attendants near the machinery may examine the bearing housings or gears and may locate the fault and remedy it without delaying the process.

In this case, even if the protective device cuts the motor from the line, are you not more interested in the signal that such action affords than in actually protecting the motor?

I like the horn idea. It seems to me that some such signal that cannot be easily suppressed will produce the most desired results.

C. O. Franklin: There is another type of thermal relay which was not mentioned. It is one which is used extensively in the protection of fractional horsepower motors, and sometimes for protecting large main mill drive motors. I refer to the snap-action thermal relay which is attached to the motor frame and opens the control circuit or operates an alarm when the motor reaches a predetermined temperature. This type of relay might be considered for the protection of some of the more important mill type motors.

J. W. Stirling: It has been the practice to protect transformers against overload on the basis of extraordinary heat in the transformer itself, not in some piece of equipment separate from the transformer. We protect the transformer from damage by secondary overloads on the basis of the ability of the transformer to withstand that temperature which will not damage the insulation and yet allow maximum loading.

I see no reason why a practical solution of that could not be applied to a mill motor.

P. J. McKeever: In the case of large motors, the

combination of the standard bimetallic element (imbedded in the windings of the motor), plus instantaneous overload relay, comes nearer to giving full protection. When the bimetallic element operates, it does take time to reset, but this is also a safeguard for the windings themselves.

The solder pot type relay is all right for motors up to and including five horsepower. On motors above five horsepower, the instantaneous relay should be used. On loads such as pumps and blowers, the bimetallic built-in element should be in series with the instantaneous overload relay. In all the above applications for protection against short circuit, I would recommend a circuit breaker be installed.

J. D. Watson: In the application of overload protection, the demand for different types of equipment is just about as varied as the different positions or locations where you can install motors. Mr. Mohler's suggestion of the alarm for overload is proving quite satisfactory in some cases. However, if you have a furnace full of slabs, you are going to run, and it doesn't make any difference what tripped the relay if you can keep going. The same motor in a different location in the same mill might require different overload protection. On the matter of a screwdown, you will have directional-overloads; one overload would be set to one value in one direction and another value in the other direction, and to pick out any one overload device would not be possible. You have to pick from a great variety of overload devices.

J. F. Reis: While the mill operating personnel is interested in the production of steel, the maintenance personnel must maintain the equipment. Therefore, the protective equipment must be engineered to meet the requirements of the particular drive. This condition should be met at all times and is most important today because of the extended delivery of replacement parts and the shortage of trained electrical and mechanical repairmen.

The use of thermal type overload relays to protect motors, as stated by Mr. Moffett, gets at the root of many of the control and motor failures in steel plants. The proposed thermal overload relays should be designed so that their operation is unaffected by steel mill dirt and corrosive gases and preferably be nonadjustable. The suggestion that the overload relay contain a time lag reset feature to permit the dissipation of excess heat stored in the motor has merit. The statement that when a furnace is loaded with hot steel ready for removal, the drive will be used despite any overload condition which may obtain illustrates a practice which induces destructive stresses in electrical and mechanical equipment and efforts should be made by the operating department to restrict such practices within economical limits.

It is my understanding that the thermal overload relay, proposed by Mr. Moffett, permits maximum safe loading of the motor and therefore uses its rated capacity economically.

J. D. Kelvie: I believe the only protection you need on mill auxiliaries is short circuit protection. Practically all overload protection I know of will be found to be shorted out after the overload has caused a delay a few times.

As far as the thermal overload relay goes, what happens at twenty below zero or one hundred ten? Isn't that going to give you a wide variation?

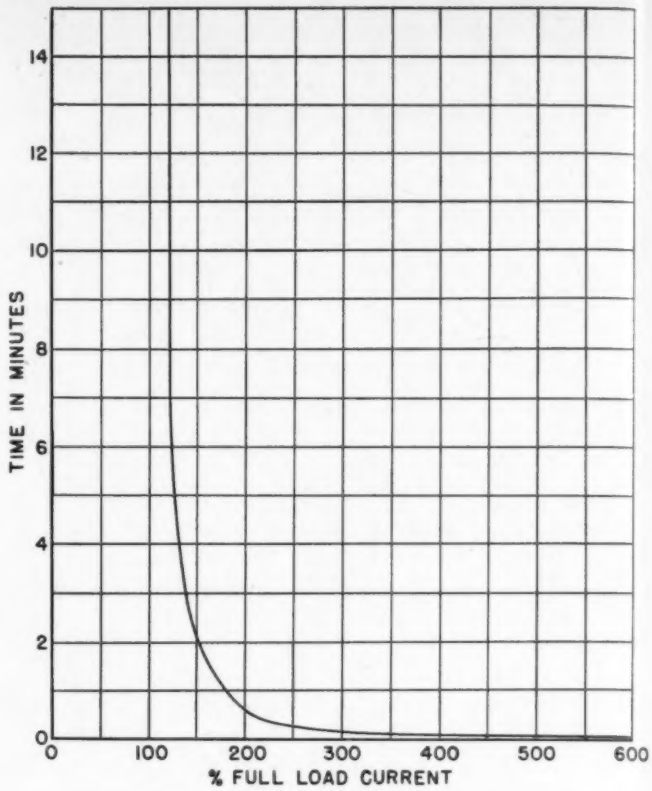

Figure A — Characteristic curve for TI-2 relay.

In cold weather all mill auxiliaries are going to be overloaded until gear shield, etc., gets warmed up and the motor must take such overloading.

I think the idea of putting on a lot of horns is good, if somebody will give us a horn that will keep working.

M. W. Smith: What are you going to do, if nobody pays any attention to the horn? Are you going to let the motor burn up or put a second control on it to trip it off?

J. S. Murray: We find that horns in steel mills are usually ignored. In fact, there are too many horns, whistles and bells in most steel mills at the present time.

The subject illustrates the unavoidable pressure which war-time industry is exerting on electrical equipment as well as many other things, including personnel, and we believe that this is the real issue, in that we are operating electrical equipment beyond all normal limits of protective devices in a great many cases. In fact, a considerable number of such devices are cut out entirely, and for this reason we believe that the conditions mentioned here are somewhat unfair to the overload relay.

However, there is no doubt that there is need for improvement in such devices, and it might well be that the Association should lend a hand to further cooperation with the control manufacturers on improvement of overload relays.

G. A. Moffett: I do not think that the TI relay is a thermal overload relay.

If you will look at the descriptive literature on this relay, you will find no mention of it being a thermal relay. The engineers have made a very ingenious use of an alloy commonly known as Invar. When Invar reaches a certain temperature, dependent upon the particular

grade of alloy used, it loses its magnetic properties. When it does so, it loses its restraining power, giving the relay the freedom of action of a straight magnetic device.

Sticking closely to the definition of overload, I do not think that the TI relay can be classified as a combination thermal and magnetic relay. The curves published on this relay show time-current characteristics which do not agree with the thermal characteristic of the mill motor or any other motor on the market.

I am firmly convinced that you can take mill type motors, have them run their duty cycle, and have them up to the allowable temperature rise of 75 degrees, and while in this condition, commutating torque can be applied and held for two minutes without seriously affecting the motor. You can take motors and submit them to something in the neighborhood of 300 heat shocks, each shock taking the motor to a maximum temperature of 200 degrees C, and in so doing you will not have taken more than 8 to 10 per cent out of the life of that motor. I believe it is not too serious when we consider that it is a serious proposition to lose the use of a motor under an emergency condition when you would like very much to have it handling the load for which it was intended.

There was another comment relative to the so-called thermoguard or thermotector protection, that is, where one should actually locate the protective device in the motor. In my opinion, it is not necessary to locate the protective device in the motor to get protection. It is true that with thermal protection built into the motor, protective elements are always in the same ambient as the motor, whereas if the relay is mounted with the usual control equipment it is located at some distance from the motor, and possibly in a different ambient. That is not an objection which cannot be overcome, because the relays can be ambient compensated. Differences in ambient conditions are only very slight objections.

Again, the thermal elements in the motor take their heat directly from a condition of current in the windings, and a condition of temperature in the iron. The thermal relays mounted remote from the motor take their temperature solely from the current to the motor.

These conditions can be adjusted so that you can get identically the same characteristic curves whether the relays are mounted with the motor or remote from the motor. The only objection there is, as I see it, to putting this protection in the motor, is that it requires the running of additional control wires between control equipment and motor. Whether or not that is a serious objection I do not know. Definitely, it is a very large objection in the general purpose field. That may not be so with steel mill auxiliaries.

G. E. Stoltz: The TI overload relay is designed to trip at some per cent of continuous load such as 100 to 120 per cent up to an instantaneous overload of 200 to 400 per cent. Its type designation TI means thermal and instantaneous protection, and its operation is a combination of magnetic and thermal principles. The load current passes through the Invar element which is an iron nickel alloy. Up to a temperature of 200 C it is magnetic and holds the relay armature in its down position. Above 200 C it becomes non-magnetic and loses its hold-down effect so that the armature is drawn to its upper position. High overload will immediately overpower the downward pull of the Invar element even though it has not had time to be demagnetized. An overload of intermediate value will in time heat the Invar current carrying element to 200 C demagnetize it which will allow the relay to trip.

Figure A is a characteristic curve of the TI overload relay, plotted between time in minutes to trip and per cent full load current. This particular curve has been plotted on the basis of tripping with 120 per cent load in seven minutes, 200 per cent load in thirty seconds, and above 400 per cent load, to trip practically instantaneously.

This relay is not a thermal relay to match the thermal time constant of a mill type motor but is designed to protect the commutator of a d-c motor and to permit starting peaks.

This relay with a thermoguard imbedded in the winding of a motor would give very complete protection if it is justified. The thermoguard is a bimetal element which can be used to close or open a circuit. For this application on a mill type motor it would be imbedded in the interpole winding and at a predetermined temperature would close a contact which would energize a relay circuit. The thermoguard uses the motor as the thermal element which removes any doubt as to its accuracy.

There are many installations that can be very well served by a TI overload relay alone. If there is any question about the thermal capacity required, a portable graphic thermal meter could be temporarily installed to determine the rms load.

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1 Direct cold water feed to nose where it is needed.
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4 Transverse, staggered baffles provide circulation for maximum employment of cooling water and elimination of sediment deposits.
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Patent No. 1,827,231
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THEORETICAL LIMITING *Efficiency* OF *Various Fuels* IN THE *Open Hearth*

. . . . a theoretical survey of various fuels for open hearth use brings out certain factors which should be borne in mind in long range consideration of problems of fuel selection and furnace design . . . .

by B. M. Larsen and C. Siddall

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▲ IN order to evaluate a fuel to be burned in a system as complex as the open hearth furnace, it is best to separate the "static" elements of the problem, mainly the quantities of heat between various temperature levels, from the "dynamic" elements, such as rate of heat transfer and flame development. Accordingly, we compare the fuels on a "static" basis, assuming that the several rates of heat transfer are so adjusted as to give a comparable temperature at certain critical points in the furnace system. Although this comparison does not furnish a complete answer to a given fuel problem, it does indicate the limiting efficiency to be expected of each fuel; with such a background, and with due consideration of the basic factors of excess air, leakage, and regenerator efficiency, it should be easier to analyze the performance of a given fuel with respect to a possible deficiency in fuel-air mixing rate or some other "dynamic" element of the problem. Moreover, it provides a basis for an estimate of the engineering possibilities of mixed gas, particularly of a mixture of blast furnace and coke-oven gas, and on certain aspects of furnace design for such a mixed fuel.

The calculations and tentative conclusions are to be regarded only as an aid in the practical problems of open hearth design; they should not be interpreted as arguments against many compromises that are unavoidable in such design. It is helpful to know all the theoretical limitations of a given problem even though an appreciable margin of efficiency may have to be sacrificed in the best all-round practical solution.

The calculations indicate that straight producer gas can benefit less from larger regenerators than perhaps any other fuel. Oil and tar gain somewhat more from deep regenerators, although even with these it is relatively more important to minimize excess air and leakage. Producer gas enriched with coke oven gas is more dependent upon efficient regeneration. With premixed coke oven and blast furnace gas, good performance depends largely upon the provision of extra deep, efficient regenerators, especially of relatively larger gas checkers, and upon such design features as will make it possible to conduct a larger fraction of the outgoing gases through the gas checkers.

Presented before A. I. S. E. Philadelphia District Section Meeting, February 3, 1945.

The data indicate that a mixture of approximately 35 per cent coke oven gas with 65 per cent blast furnace gas, premixed and preheated in a properly designed furnace, has, because of its large capacity for carrying waste heat back to the melting chamber by regeneration, the highest theoretical overall thermal efficiency of all available open hearth fuels, the next highest being tar or oil. The use of mixed gas has certain handicaps, such as loss of gas on reversal and the necessity of providing extra water-cooling; to offset these there are advantages which may result in cooler and less rapidly corroded end walls and downtake zones, slower plugging and easier cleaning of checkers. In general, a furnace having certain features specifically designed for mixed gas, seems potentially capable of an efficiency comparing favorably with that of tar or oil.

Practical experience with mixed gas is largely in contradiction, and it is quite probable that some "dynamic" limitation to heat transfer or reaction rate will enter, and restrict actual performance. Even so, those conditions which favor maximum efficiency of mixed gas may promote its more effective utilization; the problem may become important if economic shifts tend to place a premium on the use of mixed gas as fuel.

The indication that the theoretical limit of efficiency of premixed coke oven and blast furnace gas is higher than that of oil stresses the desirability of experiments at shops where blast furnace gas is available. In order even to approach within reasonable distance of this limit, however, the furnace design must be suitable, with deep regenerators, proper air-gas division of regenerator space, and provision for drawing a large proportion of outgoing gases through the gas checkers. Otherwise, such experiments are likely to be inconclusive.

The combination in which only the blast furnace gas is preheated, while the coke oven or natural gas is injected at the ports, has only one advantage over the premixed fuel, namely, that of being more nearly adapted to use in older furnaces designed originally for producer gas. In all other respects, the premixed gas has the advantage in that it gives higher thermal efficiency, better and easier flame development and cooler end and checker zones. This is still true even though the nonpremixed combination carries less blast furnace gas, for instance 40 to 50 per cent instead of 65 per cent. The thermal data tend to confirm the suspicion that, if only the blast furnace gas is preheated, there may be difficulty in obtaining sufficiently rapid flame development to transfer the high-temperature heat to the bath in the short period of traverse through the melting chamber.

By enrichment of producer gas with around 10 per cent of coke oven gas, it appears possible to realize an appreciable increase in thermal efficiency as well as to lower the temperature of end and checker zones. This enriched gas seems fairly well adapted to many older furnaces designed for producer gas, except that to realize most of the potential gain, the regenerators should be quite deep and efficient, with damper control capable of leading a larger proportion of outgoing gases through the gas chambers.

The results also seem to explain some confusing elements in past experience with regeneration in open hearth practice. For example, Dyrrsen and others have concluded that the efficiency of regeneration is sharply limited by the fact that much more heat is carried out in products of combustion than can possibly be reabsorbed and carried back into the melting chamber by the air or air plus fuel to be preheated; or, in other words that what we have called the "efficiency limit" (E_L) is low. Two factors may be responsible for this point of view: (1) It arose in large part from experience on producer gas for which E_L is naturally low, being around 65 to 70 per cent even in a tight furnace system; (2) the presence of large air leakage in most earlier furnaces, (as much as 40 to 50 per cent of all the air often leaked in between and into the hot ends of the two regenerative zones), so that E_L was often as low as 35-40 per cent. In such cases, even small regenerators 6 to 10 ft deep will give 30-35 per cent net efficiency, or a high percentage of the maximum obtainable, and larger, deeper regenerators can give only a small improvement. Even shallow checkerwork tends to overheat in such a furnace, and this tendency will be somewhat greater with deeper chambers, so that attempts to improve efficiency with greater surface area and volume of checkerwork will inevitably be unprofitable where this efficiency limit is low.

In a well designed furnace system with sealed chamber walls, draft control, insulation, etc., the leakage can be reduced to the point where E_L may be 65-70 per cent for producer gas and 70-75 per cent for oil or mixed oil and gas. A given improvement in regenerator design (by deepening the chambers, increasing heating surface area, two-pass design, etc.) can now increase the net efficiency, yet the maximum temperature of top checker brick is low enough even with deep checkerwork to permit effective cleaning. In other words, the type of fuel, the total air leakage, and the practicability of deep regenerators, which can be effectively cleaned and have low replacement or rebuilding costs, are all closely interrelated.

Calculations indicate that for producer gas the ideal gas-air division of checkers should be about 25:75 instead of the more common 40:60 ratio. At present the gas chamber is usually not utilized effectively, whereas the air chamber tends to be overloaded. When such a furnace is put on oil or tar near the end of a campaign, the reasonably clean, efficient gas chamber may now be utilized for air preheat and the furnace will give reasonably good regeneration for a short period. In general, many present furnaces have regenerators adequate for producer gas. On oil or similar fuels, although the minimizing of air leakage is of first importance, once the furnace system is maintained tight with low leakage, then extra deep regenerators, (preferably two-pass to utilize their volume better, and 18 to 20 ft in checkerwork depth), can give something like 10 per cent more useful heat from the fuel, with faster melting due to the larger heat storage in the regenerative zone.

In concluding this summary, the limitations of this treatment of the problem should be emphasized to avoid possible misunderstanding, especially on the part of the open hearth operator. We recognize that there are many fuel problems of immediate practical importance to the operator and fuel engineer, to the solution of which this discussion offers little help. Most of these immediate problems, (such as design and adjustment of burners, fuel-air proportioning methods, control of air leakage, port end design, etc.), are such that little can be con-

tributed by calculation or by laboratory experiment. On the other hand, certain longer range problems of choice and allocation of steel plant fuels are potentially of great importance, and although even these must depend largely on plant development, any partial solution or added understanding which can be contributed by calculation from available data would justify this study. As long as fuel oil is available and moderately cheap, its practical advantages are great. But if changed conditions should place a premium on the best employment of blast furnace, coke oven and producer gases, it will be important to know how to use each most effectively. The data indicate, for example, possibilities in burning enriched producer gas or coke oven and blast furnace gas mixtures, provided that certain practical conditions are met. The extent to which it is practicable to realize these conditions and approach the potential limits of fuel efficiency, can only be determined by actual plant development work

ANALYSIS OF THE PROBLEM

The general ideas underlying our evaluation of open hearth fuels have been outlined in a recent book "Basic Open Hearth Steelmaking," American Institute of Mining and Metallurgical Engineers, New York, (1944). Chapter XIV, pp. 404-445. They are: (1) the concepts of maximum theoretical flame temperature and of a "critical temperature level"; (2) a method for calculating an approximate value of the amount of "high temperature heat" available above this critical temperature level for various conditions of regenerator efficiency and of excess air and "air leakage." This high temperature heat includes not only that which goes into the steel and slag, but also all that available, above the critical temperature level, to offset loss by radiation and conduction in hearth and end zones above downtakes. These concepts help to obviate complications due to variation in operating rate, kind of charge, degree of insulation of furnace, etc., and to reduce the problem to its purely thermal or fuel engineering apects.

Our main purpose is to derive some basis for answering questions such as: (a) to what extent does regenerator efficiency vary with the fuel, and what is the maximum potential efficiency of the various fuels?; (b) what are the thermal and chemical limitations, as well as those arising from furnace design, when a mixed gas containing blast furnace gas or other special fuel is used?

It should be repeated that many problems of combustion and design are not included, also that unavoidable assumptions and approximations introduce some uncertainty into the accuracy of the results. We believe, however, that the relative effects of certain variables are reasonably accurate, and that our results may serve as an initial basis for improvement and as a reasonable approach to the consideration of mixed gases as open hearth fuel.

The open hearth fuel problem includes both a "static" and a "dynamic" aspect. The former includes the amount of heat available within given temperature limits in each of the several zones in the furnace system for variation in fuel or in regenerator efficiency. The dynamic aspect covers the rate of gas flow and of heat transfer in various parts of the structure, the mixing and combustion in the flame, etc. While it is obvious that both aspects are significant, the whole problem is too large to swallow at one gulp; hence, our treatment is limited largely to the static phase. Once the static limitations are understood, it is easier to learn whether a given fuel efficiency or rate of furnace driving is unsatisfactory because of one or more of the rate factors involved. The same is true for any complex industrial chemical process. We need first to know the amount of heat and of materials, and the equilibrium conditions, involved in the reactions; we then know what to expect, and if results do not measure up we begin to look for factors which operate to limit the results in practice.

CHARACTERISTICS OF VARIOUS FUELS AND MIXTURES

Economic conditions in Germany after the World War I led to an intensive study of the most efficient use of fuels, such as producer gas from cheap coal or mixtures of coke oven and blast furnace gas, from which there came some significant advances, as attested by the fact that recent improvements in British practice have in large measure developed from these investigations. The United States has had cheaper fuel but higher labor cost, also a greater variety of available fuels, so that conditions differ in many respects. Without going into economic questions, it certainly seems possible that in certain districts in this country it may be advantageous to make the steel works independent of fuel purchased outside, such as natural gas, oil, or coal other than for coke. This brings up the possible use of mixed coke oven and blast furnace gas, which is used exclusively in some of the more efficient British open hearth shops. Compared to Britain, we have richer ore and so produce relatively less fuel in the form of blast furnace gas. But recent improvements in design of soaking pits, reheating and other furnaces have also tended to lessen total fuel consumption, and it is timely to reconsider the question of the most effective way to use excess blast furnace gas.

Studies on producer gas have shown the advantage of using in the producer a minimum amount of steam, the exact amount depending on the moisture in the coal and the clinkering temperature of its ash. They have also indicated that it is not advantageous to preheat this gas too hot in the open hearth regenerator, in spite of the small theoretical advantage that more heat is returned to the system by the hotter fuel. This gas, as it leaves the producer, is not in chemical equilibrium, since it contains hydrocarbons along with residual CO_2 and water vapor which at high temperature react to form CO and hydrogen. In the open hearth chamber, heat transfer must be rapid in the short period of passage of the flame gases, and a luminous flame contributes materially to rapid transfer. CO_2 and H_2O radiate heat, but the presence of particles of solid carbon in the flame is a large factor in effective transfer by radiation. Producer gas normally contains about enough (but none too much) hydrocarbons and suspended carbon to produce a fairly luminous flame. At temperatures up to approximately 1850 F, the tar and hydrocarbons break down only in part to solid carbon and hydrogen and so retain

their radiating effect in the hearth zone. At higher temperatures, especially above 2000 F, however, the reaction of carbon particles or methane with CO_2 and H_2O becomes rapid, with loss of flame brilliance, which indicates the desirability of directing the outgoing gases to the air checker to such an extent as to limit the preheat temperature of the producer gas to 1850-1950 F.

With mixed coke oven and blast furnace gas (and the same chemical effects occur in mixed natural and blast furnace gas, when premixed and preheated), an opposite effect seems desirable. In such cases it is theoretically possible to mix sufficient of the gas of high hydrocarbon content to react with nearly all the CO_2 and H_2O present, and yet leave sufficient excess hydrocarbon to develop a luminous flame. Even after cooling the gases so as to remove as much water vapor as feasible, we still have a large amount of CO_2 and H_2O which it is desirable to eliminate, also an abundance of hydrocarbon from the coke oven or natural gas; therefore, in this case it is desirable, instead of trying to suppress the reaction of carbon with the CO_2 and H_2O, rather to promote this reaction by preheating the mixed gases to 2000 F or higher. Aside from the probable advantage in flame radiation in the melting chamber, such a preheated mixture has the advantage that these reactions absorb considerable heat, thereby increasing the total heating value of the fuel by as much as 10 per cent or more. Also, if such premixed gases are passed through the regenerators, the total capacity of absorbing sensible heat through both checkers is also increased. With premixture of either coke oven or natural gas with blast furnace gas, both effects combine to increase the proportion of the total heat leaving the melting chamber which can be returned to it by regeneration, as well as to change the relative proportion of outgoing gases which should flow to the gas and air regenerators.

Straight producer gas can also be enriched by admixture of 5 to 10 per cent of coke oven or natural gas. The problem then becomes much the same as for the above mixed gases, in that it becomes desirable to preheat the enriched mixture to a high temperature and thereby to increase the possible net efficiency, as is shown later.

With all mixed fuels, the question of whether to premix and preheat is also related to furnace design, in that it involves the relative fraction of outgoing gases which can be desirably directed to air or gas checkers, the arrangement of ports and dampers, and the relative areas of gas and air checkers.

FURNACE AND REGENERATOR EFFICIENCY

It is desirable to review the concept of the thermal efficiency of a fuel in the open hearth. First is the idea of "useful heat." If we define this as the heat actually put into the steel and slag, we get into complications, such as mode of operation, type of charge, insulation of structure, etc., which are not part of the essential fuel problem. Consequently, we employ as a measure of thermal efficiency, the more useful idea of "high temperature heat," this being the heat at a temperature high enough to be usefully available to the whole melting chamber and end zones of the furnace. To simplify matters, we divide the furnace system into: (1) a high temperature zone bounded by the tops of the downtakes, including melting chamber and port ends; (2) a pair of regenerative zones, bounded by the top of the downtakes and the air entrance to the flue at each end of the furnace, including downtakes, slag pockets, checker chambers and that part of the flues leading out of these chambers as far as the point of air entrance; and (3) a stack zone, including stack or waste heat boiler and flue zones between stack and air inlets (see Figure 1). This scheme is logical and fairly precise except that the division between the high temperature and the regenerative zones is somewhat indefinite.

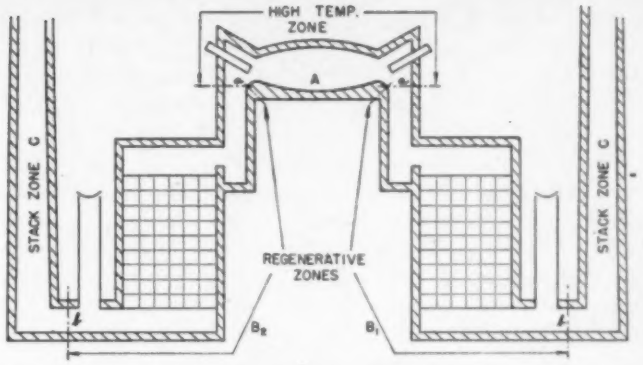

Figure 1 — Schematic diagram of section through open hearth, showing three temperature zones as set up for this discussion.

This procedure involves the concept of a "critical temperature level" which over a cycle of one heat must be the average temperature of the waste gases as they leave the high temperature zone and enter one of the regenerative zones. The fraction of the total heat input from fuel which we call the "high temperature" or useful heat is that which is delivered to the high temperature zone at any "intensity" or temperature above this critical temperature level. More specifically, it is the heat which can be dissipated to various parts of the high temperature zone beyond the sensible heat in the products of combustion at the temperatures at which they leave this zone (at points a, a in Figure 1), the mean value of these temperatures being our "critical temperature level." This level is not an exact mathematical concept and is somewhat variable from furnace to furnace, but is is useful and fairly well defined by the nature of the steelmaking process. With an extraordinarily slow melting of pure iron with no slag in a well insulated chamber, the mean critical temperature could be as low as 1900 F; but since in the open hearth, we have rapid melting entirely from above, the top surface of the charge is molten for most of the melting period; this alone raises the mean level to 2600-2800 F, while during the finishing period with slag over the metal the outgoing gases approach the end zones at around 2900-3000 F. From actual open hearth heat balances we estimate the critical temperature in practice to be between 2800 and 2900 F, and use 2860 F in the present discussion.

To simplify the treatment and because of limited data, we introduce another approximation to compensate for the heat lost from the regenerative zones out of

the system by conduction through the furnace walls, (chiefly in the downtake and slag pocket zones). This assumption is that the gases leaving the high temperature zone at an average of 2860 F enter the regenerative zone at an average temperature of 2600 F, the margin of 260 degrees being an approximate measure of the heat lost out through the walls of the regenerative zone by conduction and radiation instead of being either transferred to the incoming gases by regeneration or discharged into the stack zone. A few such approximations are unavoidable in the treatment of a complicated thermal system such as the open hearth but really do not substantially lessen the usefulness of the calculations. Since we are concerned with a comparison of the relative capacity of various fuels to produce "high temperature heat" (above our assumed critical level of 2860 F) we also should hold constant the percentage of excess air and of air leakage, variables which influence greatly the relative proportion of high temperature heat. In practice it is not possible to operate without some excess air and leakage. With less than 5-10 per cent excess air it is usually not possible to obtain complete combustion in the melting chamber; air leakage can be kept down by insulation, by tightening the furnace structure in general, and by proper draft control, but it also cannot be eliminated entirely. In the following comparisons we always assume 10 per cent excess air and 15 per cent air leakage, both based upon the theoretical amount of air required for combustion; that is, for an amount of any fuel which requires 100 lb air for complete combustion we assume that there will be the equivalent of 110 lb air outgoing in the products of combustion as they leave the high temperature zone, and that 15 lb of this leaked into the structure in the high temperature zone.

In practice, the bath reactions liberate carbon from the bath and CO_2 from limestone and thus contribute some extra weight to the outgoing gases. This is partly counteracted because the incoming oxygen oxidizes some portion of the iron, carbon, silicon, manganese and phosphorus. To simplify, we omit all these bath effects from the calculation. Their net effect is small, except in high hot metal practice; in any case, they would not much affect the relative conditions as between the several fuels.

The fuels should preferably be compared on the basis of a constant rate of input of "high temperature heat." This rate has only a small effect on thermal efficiency, yet it does have some effect because of the variable volume, hence of rate of gas flow which affects regenerator efficiency. We therefore compare fuels on the basis of a constant rate of input of high temperature heat of about 17 million Btu per hour into a 50-ton furnace unit.

With these several assumptions we are left with only two independent variables: (1) type of fuel; and (2) depth of checkerwork. Using an electrical analogue (K. Heindlhofer and B. M. Larsen, "An Electrical Analogue of the Flow of Heat in a Regenerator System," American Institute of Mining and Metallurgical Engineers, Technical Publication No. 1798, October 1944) as a calculating machine to measure regenerator efficiency, we can estimate quantities, such as those listed below, for any combination of fuel and checkerwork depth, remembering always that these are static values, valid for comparison only on the basis that certain rate factors are held constant:

1. Percentage of heat input from fuel available to the "hearth zone" above our assumed critical temperature of 2860 F;
2. Preheat temperature of air or gas, and temperature of outgoing products of combustion at the air inlets;
3. Approximate maximum temperature of brickwork in regenerative zones;
4. Volume of gaseous products per unit of high temperature heat;
5. Efficiency limit (E_L) of the perfect regenerator.

PREMIXED, PREHEATED BLAST FURNACE COKE OVEN GAS

We treat this fuel in some detail as an example of the methods of calculation, the details not given below being included in Appendix A. The composition of the two gases before mixing is shown below in terms of cubic feet of each constituent per 100 cubic feet of dry gas, on the basis that each gas has been cooled and dried to a maximum of 2.5 per cent water vapor by volume as it reaches the mixing station:

Constituent	Coke oven gas	Blast furnace gas
CO_2	1.4	13.0
CO	5.4	26.0
C_2H_4	3.2	.....
CH_4	28.7	0.5
C_2H_6	0.8	.....
H_2	54.6	1.7
H_2S	0.6	.....
N_2	4.9	58.8
O_2	0.4	.....
H_2O	2.5	2.5
Total	102.5	102.5

The heat of combustion, or fuel value, of these two gases is respectively 504 Btu and 95 Btu per cu ft of wet gas. When they are mixed and preheated by passage through a regenerator, the following reactions begin to occur about 1750 F and proceed with increasing speed as the temperature increases:

	Heat absorbed, Btu	
$CH_4 + CO_2 \rightarrow 2\ CO + 2H_2$	106,400	(1)
$CH_4 + H_2O \rightarrow\ CO + 3H_2$	88,500	(2)
$CH_4 + \rightarrow\ C + 2H_2$	32,300	(3)

With excess of coke oven gas, and sufficient time at high temperature, essentially all the CO_2 and water vapor will disappear. A preheat to 2000 F or more probably is necessary to enable these reactions to approach completion in the short period of travel through the regenerative zone, but we can vary the depth of checkerwork and the proportion of outgoing combustion gases through the gas checker so as to obtain a sufficiently high preheat temperature. We therefore may assume that the gases react sufficiently to leave not more than about 2.0 per cent CO_2 and 0.5 per cent H_2O in the preheated mixture flowing to the ports.

Another consideration is the desirability of obtaining

in the combustion chamber as luminous a flame as possible, which is favored by the presence of heavy hydrocarbons or of suspended carbon particles in the gas. This makes it necessary to use enough coke oven gas to give an appreciable excess of hydrocarbon over that required to react with nearly all the CO_2 and H_2O present. We calculate that after reaction a mixture of 35 parts by volume coke oven gas and 65 parts of blast furnace gas should contain an excess of about 4 per cent methane or its equivalent; assuming this to be completely decomposed by reaction (3) above, this is equivalent to an excess of carbon of 0.15 lb per 100 cu ft of raw gas mixture. All this excess carbon may not be carried up to the ports; we have assumed arbitrarily that ⅓ of it remains deposited on the checker brick surface to be oxidized and carried out to the stack on the next half of the reversal period, ⅓ reacts with iron oxide dust in the checkerwork and comes to the ports as CO, and the remaining ⅓ (or 0.05 lb) reaches the flame zone as suspended carbon. These assumptions are unimportant thermally, being made here merely to indicate the possible effects. (Of course, the amount of hydrocarbon gas or of suspended carbon particles would be important to flame luminousity, but at this point we enter the experimental phases of the problem).

On this basis, 100 cu ft of the 35:65 gas mixture are then represented by the following analyses, to show the changes in the passage through the regenerator, provided only that the regenerator raises the final preheat temperature to around 2000F or more; the analyses have been simplified to give an approximately equivalent gas, with H_2S and hydrocarbons other than CH_4 eliminated.

	Raw Gas mixture, cu ft	Reacted gas after passage through checkers		
		Cu ft	Vol. %	Lb
CO_2	8.8	2.5	2.0	0.31
CO	18.3	34.1	28.0	2.66
CH_4	12.4	.....	.....	.....
H_2	19.2	45.8	37.6	0.26
N_2	38.9	38.9	31.9	3.03
H_2O	2.4	0.6	0.5	0.03
C (solid)	.....	.....	.....	0.05
	100.0	121.9	100.0	6.34

As a result of reactions (1), (2) and (3) above, the original 100 cu ft has expanded to 122 cu ft (all volumes referred to standard temperature and pressure) in its passage through the regenerative zone. The raw mix had a fuel value of 238 Btu per cu ft, or a total of 23,800 Btu for 100 cu ft; the reacted gas has a heating value of 210 Btu per cu ft or a total of 25,500 Btu for the product of the original 100 cu ft of raw mixture, an increase of 7 per cent in fuel value due to the heat absorption in the regenerative zone by the endothermic reactions (1) and (3) above. This represents a transfer of heat from the regenerative to the high-temperature zone of the furnace in the form of "potential" heat stored by chemical reactions which add to the heat transferred as "sensible" heat stored in both gas and air.

For each 100 cu ft of raw gas mixture the theoretical air requirement for perfect combustion is 200 cu ft. Assuming 10 per cent excess air, the air equivalent in the products of combustion is 220 cu ft of which 190 cu ft pass through the incoming regenerative zone, assuming 15 per cent air leakage. The products of combustion total about 300 cu ft (see Appendix A for details), comprised as follows:

Products of combustion per 100 cu ft of raw gas mixture

Constituent	Normal volume, cu ft	Weight, lb	Per cent by volume
O_2	4.1	0.37	1.4
N_2	210.1	16.38	69.6
CO_2	38.1	4.67	12.6
H_2O	49.7	2.33	16.4
Total	302.0	23.91	100.0

Based on an arbitrary input rate equivalent to oil at 180 gal per hr or a net of 26 million Btu per hour (7200 Btu per sec), we calculate that the volume of mixed and reacted gas which must arrive at the incoming port corresponds to 105,000 cu ft of raw gas mixture per hour, and we can then determine the corresponding flow of air and of mixed gas through incoming checker chambers and of products of combustion through outgoing checker chambers, also the corresponding heat absorbing capacity of these gas streams. The heat absorbing capacity of 100 cu ft of mixed gas per degree F is 3.92 Btu per* and of the 190 cu ft of air for combustion is 4.04 Btu per degree F. Since these two are so nearly equal, and since we probably should favor the gas checker in order to obtain a high preheat temperature, we make an equal division of gas and air checker capacity; that is, the cross-sections of gas and air checkerwork at each end are assumed to be equal instead of in the ratio of about 40:60 commonly used in producer gas furnaces. The heat absorbing capacity of the 302 cu ft of products of combustion (from each 100 cu ft of raw mixed gas) is 7.55 Btu per degree F.

We now have all the data required to determine the regenerator efficiency by means of the electrical analogue, except the depth of checkerwork and the relative proportion of total outgoing gases to be allotted to the air and gas checkers. After a few trials we found that, with a total checkerwork† cross section of 180 sq ft, a depth of 20 ft and about 57 per cent of the products of combustion diverted to the gas checker, the indicated preheat of the mixed gas is 1980 F, which is considered high enough to assure the degree of decomposition of hydrocarbons and of reduction of CO_2 and H_2O assumed above. The remaining 43 per cent of outgoing gases preheat the air to 1660 F. With these data we calculate the available high temperature heat, for this mixture of

*About 1/3 of this is due to heat absorption by the above chemical reactions — this "chemical" heat absorption occurs mainly in the hotter portion of the regenerative zones, but we assume it to be distributed uniformly over the whole regenerator — previous studies have shown that such a simplification has relatively little effect on regenerator efficiency.

†This is somewhat arbitrary checker design; with a more generous cross section the depth could be 16-17 ft with about the same effect. In any case, such a regenerator is some 20-30 per cent larger than those used in nearly all present furnaces.

TABLE I

	Cu ft per hr	Temp. range, °F	Fuel value or sp. heat Btu per cu ft	Btu per hr
Reacted mixed gas — potential heat	128,000	.....	210.	26.9×10^6
Reacted mixed gas — sensible heat	128,000	(1980-60)	0.0211	5.2×10^6
Air — sensible heat	200,000	(1655-60)	0.0212	6.76×10^6
				38.86×10^6
Outgoing gases — sensible heat	317,000	(2860-60)	0.0242	21.5×10^6
Difference, net heat available to high temperature zone		.....	.....	17.36×10^6
Per cent high temperature heat (unreacted mixed gas)		$\frac{17.36 \times 10^6 \times 100}{105{,}000 \times 238} = 70\%$		

TABLE II

	Cu ft per hr	Fraction of total	Temp. range, °F	Mean sp. ht.	Btu per hr.
Outgoing gases — gas checker	317000	x 0.57	x (2600-60)	x 0.0242 =	11.10×10^6
Outgoing gases — air checker	317000	x 0.43	x (2600-60)	x 0.0242 =	8.38×10^6
Preheated reacted gas	128000		x (2600-60)	x 0.0298 =	9.69×10^6
Preheated air	200000		x (2040-60)	x 0.0212 =	8.38×10^6

$$E_L = \frac{9.69 + 8.38}{11.10 + 8.38} = 92.7\%$$

35 per cent coke oven and 65 per cent blast furnace gases, with 20 ft checker depth, as shown in Table I.

It should be remembered that this 70 per cent is that part of the total heat value of the fuel available not only for heating the charge, but also to make up the various heat losses in melting chamber and end zones; also, that although the net value of 23,800 Btu per 100 cu ft of mixed gas is increased to 25,600 Btu at the ports by storage of potential or "chemical" heat, we must use the lower value in computing the percentage of heat input which is available to the high temperature zone of the system.

We also calculate for the above case the so-called "efficiency limit" E_L, that is, the percentage of the heat in the outgoing gases which could be returned if we had perfect regenerators, i.e., whose efficiency in heat interchange is 100 per cent. E_L is the total heat absorbing capacity of the air and fuel relative to that of the products of combustion in the respective checkers. (See Table II.)

In the gas checkers, to which 57 per cent of the outgoing gas is allotted, the products of combustion have more heat capacity than the mixed gas, which can therefore be heated to the top regenerative zone temperature of 2600 F. In the air checker, which gets only 43 per cent of the outgoing gases, the incoming air has the greater heat capacity and can absorb all of the 8.38 million Btu available in being heated to 2040 F. The high apparent value of 0.0298 for the mean specific heat of the mixed gas is because we added the "potential" heat absorbing capacity by chemical reaction to the true specific heat of 0.0211; this is not a true specific heat, but is convenient to use in these calculations to represent the total heat absorbing capacity. This high value of 93 per cent for E_L tells us that this mixed gas is well adapted for a regenerative furnace system, the efficiency being much higher than that for producer gas, also higher than that obtainable with oil or coke oven gas.

We may now make a similar computation using a checker depth of 12 ft, a size about average for a large number of present furnaces, most other factors such as checker area, brick setting, excess air and leakage remaining the same as above for the 20 ft checker depth; but in order to be truly comparable, i.e., with the same rate of driving, we must again have about 17 million Btu of high-temperature heat per hour. To get this with less efficient regeneration it is obviously necessary to increase the rate of fuel input; by successive approximations we find that this rate must be increased from 105,000 to 125,000 cu ft per hour of raw gas mixture. But to be really comparable, we also must have the same preheat of nearly 2000 F in the gas mixture at the ports; and this makes it necessary to change from a 50:50 to a 70:30 division of gas-air checker areas also, to divert 75 per cent instead of 55 per cent of the outgoing gases to the gas checkers. With these conditions we find that 57 per cent of the heat is available to the high temperature zone. This comparison demonstrates the great advantage of efficient regeneration with mixed gas. The smaller checkers sacrifice 19 per cent of the net fuel efficiency, and increase the diversion of outgoing gas to gas checkers to an impracticably high level. Summarizing, such calculations tell us quite a few significant things. Somewhat over 1 part of coke oven to 2 parts of blast furnace gas is needed to reduce most of the CO_2 and H_2O present and yet leave excess carbon or tar for

a luminous flame; but these reactions increase the heat absorbing power of the mixture in the gas checker by about 50 per cent. Both factors tend to produce high temperature heat more efficiently and to give cooler regenerative zones; it would seem advisable therefore on such fuel to design a furnace with some 25 per cent or more of increased regenerator capacity, as compared to many present newer furnaces, so as to preheat the gas to around 2000 F or higher. With such regenerators, divided equally between gas and air at each end, at least 50 per cent, and possibly more, of the outgoing gases must go to the gas checker system. This in turn indicates the desirability of a furnace design favorable to such a gas flow, such as sliding damper control in flues, for example, to make it possible to divert enough of the outgoing gas to the gas checkers and at the same time maintain such slopes and cross-sections in inlet gas ports as to give proper flame direction. If excess air can be kept to 10 per cent and air leakage to 15 per cent, then about 70 per cent of the heating value of the fuel is potentially available to the high temperature zone, if large regenerators are used. These results are to be regarded as relative rather than absolute; nevertheless they are useful and significant in comparing various fuels.

THERMAL CALCULATIONS FOR OTHER FUELS

By methods analogous to those used for the treatment of premixed blast furnace and coke oven gas fuel above, similar calculations were made for the following fuels:

Producer gas.
Producer gas enriched with 10 per cent coke oven gas — premixed.
Natural gas-blast furnace gas, premixed.
Coke oven gas-blast furnace gas, not premixed.
Coke oven gas.
Blast furnace gas.
Oil.

PRODUCER GAS

We assume a producer gas of the following composition, entering the bottom regenerative zones at 1200 F:

CO_2 — 4.6%
C_2H_4 — 0.8%
CO — 24.8%
H_2 — 9.7%
CH_4 — 3.1%
N_2 — 53.7%
H_2O — 3.3%

The net fuel value of this gas is 156 Btu per cu ft, the sensible heat is 24 Btu, making a total thermal value of 180 Btu per cu ft.

As noted above, it is probably not advantageous to preheat producer gas above about 1850-1900 F because, at higher temperatures, there is too much tendency toward a loss of radiating power of the flame, because the limited amounts of tar and hydrocarbons then tend to be oxidized by the CO_2 and H_2O present. Heat storage in the gas checker is therefore limited since the gas enters at 1200 F and should only be preheated to 1850 F. Assuming the moderate checker depth of 12 ft for the first case, we calculated that only 25 per cent of the outgoing gases would be needed to give this gas preheat, so the division of gas to air checker cross-section was made 30:70 instead of the more usual division of 40:60 in gas producer furnaces.

These conditions being set, the gas preheat was determined to be 1870 F and the air preheat 1900 F. In order to obtain 17 million Btu high temperature heat per hour, the gas input must be 195,000 cu ft per hour. The net efficiency or percentage of high temperature heat is then 50 per cent. (See Table III.)

For the comparable case with deep checkers, it seemed useless to increase the depth of the gas checker, since it was already very efficient; so we calculated for a case with the same 12 ft depth of gas checker but with the air checker deepened to 20 ft. The gas input can then be reduced to 173,000 cu ft per hr (as compared to 105,000 cu ft per hr for the mixed gas fuel with deep checkers) and the percentage of high temperature or available heat increased to only 55.2 per cent compared to 70 per cent for the mixed gases with deep checkers. The limiting regeneration efficiency with perfect regenerators, or E_L = 70 per cent as compared to 93 per cent for the mixed gases.

Thus straight producer gas is a lower grade fuel than properly preheated mixed gas and is potentially less

TABLE III

	Cu ft per hr	Temp. range °F	Fuel value or sp. ht., Btu per cu ft	Btu per hr
Producer gas — potential heat	195000 x		156	= 30.5 x 10^6
Producer gas — sensible heat	195000 x	(1870-60) x	0.021	= 7.4 x 10^6
Air — sensible heat	231000 x	(1900-60) x	0.0212	= 9.0 x 10^6
Total input				46.9 x 10^6
Outgoing gases — sensible heat	430000 x	(2860-60) x	0.0243	= 29.3 x 10^6
Net heat available to high temperature zone				17.6 x 10^6

$$\text{High temperature heat} = \frac{17.6 \times 10^6 \times 100}{195000 \times 180} = 50.1\%$$

efficient; it depends less upon efficient regeneration than mixed gas, and is less well adapted to a regenerative furnace because of the poor heat storing capacity of the hot producer gas. In a producer gas furnace with ordinary checker depth we already tend to need a diversion of about 75 per cent of outgoing gases to the air checkers by damper settings and the air checker consequently tends to run hot, that is, periods occur when the driving rate of the furnace is limited by the high peak temperature in the air chamber. With a deepened air checker only, there is only a small increase in thermal efficiency with slightly higher peak temperature; deepening the gas checker also gives even smaller additional increase in fuel efficiency, and we would have to "crowd" still more of the gases to the air checker so that the peak temperature of the latter would be still higher. This question of the peak checker brick temperature with different fuels is discussed later.

With mixed coke oven-blast furnace gas, a moderate checker depth makes it desirable to divert most of the outgoing gases to the gas chamber, (much more difficult than diversion to the air chamber because of restricted gas port areas) in order to preheat the gas high enough for the desired reaction with CO_2 and H_2O. With deep checkers, we need only about half, or a little more, of the gases to the gas checker; we get higher air preheat and a higher thermal efficiency, yet there is no tendency for the peak temperature in either chamber to run too high because both gas and air have a high capacity for heat absorption, which is reflected in the high E_L value of nearly 93 per cent. With straight producer gas, E_L is only around 65-70 per cent; this does not mean that efficient regeneration is not of some value even with producer gas, but simply that it is much less valuable than with certain other fuels, especially with premixed coke oven and blast furnace gas.

ENRICHED PRODUCER GAS

It seems possible to increase the efficiency of producer gas by admixture of about 10 per cent by volume of coke oven gas, (4-5 per cent of natural gas might also be used for the same purpose) preheating the mixture to approximately 2000 F or more, and thereby reducing part of the CO_2 and H_2O to give at the ports a mixed gas similar to a preheated coke oven and blast furnace gas mixture. Starting with the same producer gas as above, and "simplifying" the analysis of the coke oven gas, we have the following change for 100 cu ft of raw gas mixture passing through the regenerative zone, making the same assumptions as in the previous discussion of mixed gas:

	Raw mix, cu ft	Reacted gas, cu ft
CO_2	4.3	2.5
CO	22.6	29.8
H_2	13.8	31.5
CH_4	7.5	.....
N_2	48.6	48.6
H_2O	3.2	0.6
C	.....	1.0 (solid)**
Total	100.0	113.0

**The 1.0 per cent of carbon in the reacted gas at the ports is solid carbon, expressed here as the volume it would have if in vapor form.

Thus, 100 cu ft of raw mix of 191 Btu per cu ft heating value expands to 113 cu ft of reacted gas with 174 Btu per cu ft heating value at the ports, an increase of about 3 per cent. Enrichment by addition of 10 per cent coke oven gas increases the possible heat interchange in the gas checkers in three ways: (1) the heat absorbing reactions produce the same increase in heat absorbing capacity as if the true specific heat of the gases had been increased from 0.023 to 0.036 Btu per cu ft; (2) the mixture enters the regenerative zones at about 1100 F instead of 1200 F; (3) there is now, instead of an objection to heating the straight producer gas above 1850 F, an advantage in heating the enriched mixture to 2000 F or higher to obtain the desired reactions in the regenerative zones.

We calculated examples for this mixture, using a gas-air checker division of 40:60 as is common in producer gas furnaces. With 140,000 cu ft per hr input of raw gas mixture and 12 ft checker depth, we get a thermal efficiency of 55.6 per cent as compared to 50.1 per cent for the producer gas alone; but it would be necessary to divert 55-60 per cent of the outgoing gases to the gas checker to approach 2000 F preheat, which would perhaps be difficult with the ordinary design of producer gas furnace.

TABLE IV

	Cu ft per hr	Temp. range °F	Fuel value or sp. ht. Btu per cu ft	Btu Per hr
Enriched gas — potential heat	141,000 x		x 174.	= 24.6×10^6
Enriched gas — sensible heat	141,000 x	(1995-60) x	0.0211	= 5.76×10^6
Air — sensible heat	182,000 x	(1975-60) x	0.0212	= 7.40×10^6
Total input				37.76×10^6
Outgoing gases — sensible heat	314,000 x	(2860-60) x	0.0242	= 21.26×10^6
Net heat available to high temperature zone				16.5×10^6

$$\text{High temperature heat} \ldots\ldots \frac{16.5 \times 10^6 \times 100}{125{,}000 \times 212} = 62.3\%$$

TABLE V

	Cu ft per hr	Temp. range, °F	Fuel value or sp.ht., Btu per cu ft	Btu per hr
Coke oven-blast furnace gas mix — potential heat	121,000 x		238	= 28.80 x 10^6
Blast furnace gas — sensible heat	78,700 x	(2410-60) x	0.0226	= 4.18 x 10^6
Air — sensible heat	243,000 x	(1970-60) x	0.0212	= 9.83 x 10^6
Total input				42.81 x 10^6
Outgoing gases — sensible heat	379,000 x	(2860-60) x	0.0243	= 25.80 x 10^6
Net available high temperature heat				17.01 x 10

$$\text{High temperature heat} = \frac{17.01 \times 10^6 \times 100}{28.8 \times 10^6} = 59.0\%$$

If the checker depth were 20 ft, the comparable input becomes 125,000 cu ft per hr of raw gas mix, and it would be necessary to divert only about 45 per cent of the outgoing gases to the gas checker; under these conditions the calculated thermal efficiency was 62 per cent as compared to about 55 per cent for straight producer gas with deep checkers. The calculation is given in Table IV.

The value of 212 Btu per cu ft is the heating value of raw mix plus sensible heat in the 90 per cent of producer gas. For this case E_L = 78.2 per cent, as compared to about 70 per cent for straight producer gas. Thus the indications are that this enriched gas should give an appreciably higher thermal efficiency than straight producer gas, mainly because it is better adapted to take advantage of a furnace design with deep efficient regenerators; an important practical advantage is the relative reduction in volume of outgoing gases from 430,000 to 314,000 cu ft.

PREMIXED NATURAL AND BLAST FURNACE GAS

This case is very similar to premixed coke oven-blast furnace gas; but because this mixture might be used experimentally to study mixed gas fuel if coke oven gas were not readily available, it seemed desirable to go through the calculation. Taking blast furnace gas of the same composition as before, and the following natural gas composition

CO_2 — 0.3%
C_2H_6 — 18.3%
CH_4 — 80.6%
N_2 — 0.8%

we find that a mixture of 14 per cent natural gas with 86 per cent blast furnace gas suffices to react with the CO_2 and H_2O present, and leaves some excess carbon as before. Composition of the raw mixture and the reacted gas mixture follows:

	Raw mixture, cu ft	Reacted gas, cu ft
CO_2	10.9	2.5
C_2H_6	2.5	.....
CH_4	11.6	.....
N_2	49.8	49.5
H_2	1.4	34.0
CO	21.7	42.4
H_2O	2.1	0.6
C	.....	(0.07 lb)
Total	100.0	129.0

Here 100 cu ft of raw mix at 235 Btu per cu ft heating value increase to 129 cu ft reacted gas at the ports with 196 Btu per cu ft; an increase from 23,500 to 25,300 Btu per 100 cu ft raw mix, or about 7.7 per cent. With 20 ft deep checkers, a 60:40 gas-air checker division, 60 per cent of the products to the gas checker being required to heat the gas mixture to about 2000 F, and 108,000 cu ft per hr raw gas input, we find E_L to be 94 per cent and the indicated high temperature heat or efficiency 66 per cent. Compared to the coke oven-blast furnace mix, the efficiency appears slightly lower, the need for heat in the gas chamber somewhat greater, so that in general this mixture is even more dependent on large, efficient regenerators for best performance when premixed and preheated.

COKE OVEN-BLAST FURNACE GAS, NOT PREMIXED

These two gases can perhaps also be used without premixing by preheating only the blast furnace gas and injecting coke oven gas (or natural gas) into the port and zone of the melting chamber. For this case we assumed the same 65 per cent blast furnace — 35 per cent coke oven gas mixture as before, with 20 ft checker depth, a 40:60 gas-air division at each end, and outgoing gases divided ⅓ to the gas checkers and ⅔ to the air

checkers, with an input rate of 121,000 cu ft per hr total of the two gases. This gave the results for available high temperature heat set forth in Table V.

Corresponding figure for premixed coke oven-blast furnace gas was 70 per cent, the difference being due to the heat-storing capacity of the added coke oven gas as sensible heat plus that of the heat absorbing reactions (between CO_2 and H_2O and the hydrocarbons) as potential heat.

A similar calculation assuming 12 ft checker depth and an input 137,000 cu ft per hr gave a high temperature heat percentage of 53 per cent. The gain in efficiency here from deep checkers is less than with the premixed gases; but since in practice the main difficulty in using this fuel without premixing may well be that of obtaining quick enough mixing and flame development in the port end zone, the lower input rate possible with deeper checkers might be of practical importance.

In such a comparison between the same gases with and without premixing these "static" values tell only part of the story. This is true for any fuel, but especially here where with cold coke oven gas injected in or near the flame zone, the rate of mixing and burning may become of predominant importance. The "static" data tell us that while with such a practice the possible thermal efficiency is lower than with the premixed gases, yet we should obtain reasonably good results, given efficient regenerators, low leakage and low excess air. The attainment of this indicated efficiency depends, however, upon getting such rapid mixing, flame development and heat transfer in the melting chamber that the critical temperature of the gases leaving the zone at the downtakes will be down to the assumed mean of 2860 F. Blast furnace gas alone does not give a high flame temperature; its flame lacks brilliance and is dilute in the sense of available heat per unit volume. Injected coke oven gas perhaps lends some brightness and radiating power, but on the other hand its tendency as it first mixes with the blast furnace gas is to absorb some heat due to its reaction with CO_2 and H_2O; this may delay the development of maximum flame intensity so that there would be insufficient time for transfer of enough heat to the bath. Thus, we might have an average gas temperature at the outgoing downtake considerably above the assumed mean "critical temperature" of 2860 F. This higher temperature, along with lowered thermal efficiency and slower rate of input of high temperature heat, would increase the tendency toward excessive port end temperatures, perhaps to the extent of forcing a decrease in rate of fuel input, which would still further decrease the input of heat available for the bath. Substituting natural gas for coke oven gas in this case leaves the "static" factors essentially the same, the only difference being that natural gas injected at the ports should lend more luminosity to the mixture.

Such secondary effects, or other limitations caused by rate effects in general, might be present with any fuel; as mentioned above, this means that the present treatment of the problem cannot be complete. However, if we know the possible results with a given fuel under certain assumed conditions, and check up on leakage, furnace design and excess air, indicated as necessary by the "static" treatment, we can then begin to look for "dynamic" limitations to account for a poor result in any given case; we thus have a logical method of study of complex fuel problems.

STRAIGHT COKE OVEN GAS

Preliminary calculations for the above coke oven-blast furnace gas, not premixed, but with the percentage of coke oven gas increased to 50-60 per cent, indicate an efficiency only slightly higher than for the 35-65 per cent mixture. This further enrichment decreases the amount of CO_2 and accompanying nitrogen, also the sensible heat carried back because of the smaller volume of blast furnace gas. This is clearer in the limiting case of 100 per cent coke oven gas. With 20 ft checker depth and all the checker cross-section at each end devoted to air preheat, the calculation for a fuel input of 51,500 cu ft per hr straight coke oven gas is summarized in Table VI.

This indicated efficiency is but little above the value 59.0 per cent for the 35:65 coke oven-blast furnace mixture (not premixed), indicating that the proportion of coke oven gas should not be critical within the range of 30-60 per cent when the gases are not premixed except as it may affect the ease of mixture and of flame development.

STRAIGHT BLAST FURNACE GAS

Going to the other extreme of straight blast furnace

TABLE VI

	Cu ft per hr	Temp. range, °F	Fuel value or sp. ht., Btu per cu ft	Btu per hr
Coke oven gas — potential heat	51,500 x		x 504	= 26.0 x 10^6
Air — sensible heat	231,000 x	(2215-60) x	0.0212	= 10.55 x 10^6
Total input				36.55 x 10^6
Outgoing gases — sensible heat	305,000 x	(2860-60) x	0.0239	= 20.40 x 10^6
Net high temperature heat				16.15 x 10^6

$$\text{High temperature or available heat} = \frac{16.15 \times 100}{26.0} = 62.2\%$$

TABLE VII

	Cu ft per hr	Temp. range °F		Fuel value or sp. ht., Btu per cu ft		Btu per hr
Blast furnace gas — potential heat	300,000		x	95.0	=	28.5 x 10^6
Blast furnace gas — sensible heat	300,000	(2200-60)	x	0.0227	=	14.57 x 10^6
Air — sensible heat	200,500	(2125-60)	x	0.0212	=	8.77 x 10^6
Total input						51.84 x 10^6
Outgoing gases — sensible heat	491,500	(2860-60)	x	0.0249	=	34.30 x 10^6
Net high temperature heat						17.54 x 10^6

$$\text{High temperature heat} = \frac{17.54 \times 100}{28.5} = 61.6\%$$

TABLE VIII

	Gals or cu ft per hr	Temp. range, °F		Fuel value per gal or sp. ht. per cu ft		Btu per hr
Fuel oil — potential heat	190		x	140,000	=	26.6 x 10^6
Air — sensible heat	251,000	(2200-60)	x	0.0212	=	11.4 x 10^6
Total input						38.0 x 10^6
Outgoing gases — sensible heat	306,000	(2860-60)	x	0.0244	=	20.9 x 10^6
High temperature heat						17.1 x 10^6

$$\text{High temperature heat} = \frac{17.1 \times 100}{26.6} = 64.3\%$$

gas, we have a fuel which almost certainly will not make steel; yet it is interesting to indicate the probable reasons for this by comparable calculations. Since its heating value is less than 100 Btu per cu ft, we can foresee that it must have a high input rate and very efficient regenerators. Starting with the case of 20 ft checker depth and an input of 273,000 cu ft per hr (compared to 105,000 cu ft per hr of premixed coke oven-blast furnace gas) the indicated thermal efficiency is 52.5 per cent, only a little below that for producer gas at this checkerwork depth. However, the high temperature heat was only 13.6 million Btu per hr, considerably below our assumed standard rate of 17 million. Increasing the checker depth to the impracticable level of 40 ft, and the input to 300,000 cu ft per hr we obtain the desired rate of high temperature heat development as shown in Table VII.

This shows that with a very high input rate and extremely efficient regenerators, blast furnace gas could make steel, if certain heat transfer rates could be realized. The checker chambers would have to be so big as to be almost hopelessly impracticable; but assuming we could build such regenerators, they would return the large percentage of heat carried by the large volume of combustion gases out of the high temperature zone so effectively that high temperature heat would be produced at a rate comparable to other fuels. The difficulty then would be that the gases, because of their enormous volume would pour through the melting chamber too fast to transmit this high temperature heat fast enough (from an almost transparent, poorly radiating flame), and on leaving the high temperature zone would not be cooled down to a comparable critical temperature level, and as a result the bath would be too cold and the port end and downtake zones probably melted down by excessive temperature.

FUEL OIL

Fuel oil and tar would be expected to have about the same thermal value as coke oven gas. Each is a concentrated fuel which is not preheated; the only obvious difference is that the coke oven gas flame radiates relatively poorly and is lighter so it cannot be directed and impinged down over the slag so effectively. Calculation shows, however, that oil is somewhat more efficient thermally.

For oil or tar assumed to be 90 per cent carbon and 10 per cent hydrogen, and an assumed heat value of 140,000 Btu per gal with a 20 ft checker depth, and an input rate of 190 gal per hr, we have results as shown in Table VIII.

This value of 64 per cent compares with 62 per cent for coke oven gas and 70 per cent for premixed coke oven and blast furnace gas. A similar calculation for 12 ft checkers and 210 gal per hr oil input gave a value of 57 per cent.

TABLE IX

COMPARISON OF CALCULATED EFFICIENCY OF SEVERAL FUELS

	Per cent high temperature or available heat		Mean temperature of outgoing gases at air inlets	
	Depth of checkers, ft			
	20	12	20	12
Premixed coke oven and blast furnace gas	70	57	770	1140
Premixed natural and blast furnace gas	66	..	760	....
Oil	64	57	1090	1340
Producer gas plus 10 per cent coke oven gas, premixed	62	56	1120	1320
Coke oven gas	62	56	1170	1355
Coke oven and blast furnace gas, not premixed	59	53	1130	1320
Producer gas	55	50	1360	1525
Blast furnace gas	53	..	960	....

COMPARATIVE FUEL EFFICIENCIES

Table IX summarizes the "available heat" values calculated for the various fuels discussed above. The indicated mean temperature of the waste gases leaving the regenerative zone is included to show that this temperature is not directly related to the thermal efficiency. For a constant top temperature of the gases entering the regenerative zone, the temperature of the gas leaving this zone does vary inversely with the regeneration efficiency. It also shows some trend upward with decreasing efficiency of the whole system (that is, the percentage of "available heat"), but there is no definite relationship because the volume of outgoing gas for a given amount of high temperature heat differs both for different fuels and for varying percentage of excess air with the same fuel. This is indicated clearly by the fact that blast furnace gas, with the lowest overall efficiency, gives a low waste gas temperature, but its volume is much larger than for any of the other fuels.

The difference between columns 2 and 3 expresses the gain in available heat corresponding to an increase of regenerator size from about the average of present furnaces to 20-30 per cent larger than those of most modern furnaces. This gain varies from about 5 per cent for producer gas to 7 per cent for fuel oil and to nearly 13 per cent for premixed coke oven-blast furnace gas, showing that the potential gain in efficiency from extra deep efficient regenerators is not the same for all fuels.

With moderate size regenerators, the indicated efficiency of fuel oil and premixed coke oven and blast furnace gas is the same; but with very efficient regenerators, it appears that the mixed gas would be appreciably more efficient than fuel oil or tar. There seems to be no substantiation of this conclusion from data on existing mixed-gas furnaces, as far as is known to us; in fact, the best fuel records to date seem to have been made on oil furnaces. This may be due in part to improper design and inadequate regenerators, inadequate insulation and control equipment on existing mixed-gas furnaces; also certain "dynamic" factors, such as the rate of heat transfer from flame to bath probably operate in favor of tar or oil. Nevertheless, a furnace designed properly for mixed-gas fuel, with adequate regenerators, good insulation, minimum excess air and leakage, and rapid flame development and control, might well have a reasonably high efficiency.

Enriched producer gas and coke oven gas come next below fuel oil (and tar) and appear to be about equal. We suspect that enriched producer gas would give a better radiating and heavier flame with more kinetic energy to help it to sweep down close to the bath than straight coke oven gas. This would not hold for coke oven gas enriched with tar or oil.

The table indicates that the thermal efficiency of coke oven-blast furnace gas, not premixed, is much below that of the same gases premixed. If the regenerators are adequate in both cases, we feel this difference will hold in practice; also that the kinetic effects of flame development and heat transfer are probably more important with the gas not premixed, so that the difference would be even greater than that indicated by the table. Apparently, coke oven and blast furnace gas, not premixed, should be more efficient than straight producer gas, but this will probably be dependent on getting a rapid mixing and flame development as the cold coke oven gas is injected into the preheated blast furnace gas at the ports. Otherwise, we suspect that the producer gas would be definitely superior. The indicated improvement by enrichment with 10 per cent coke oven gas would seem worth careful consideration by shops designed for the use of producer gas.

Straight blast furnace gas is the poorest fuel, even with a regenerator as large as is practicable, on the basis of the "statics" of the problem only. As discussed above, limitations of flame development and heat transfer will undoubtedly make this fuel even less effective than the figures in the table indiate.

RELATIVE GAS VOLUMES FOR VARIOUS FUELS

Insight into the dynamic aspect of the general problem can be obtained from the relative volume of gases involved in the production of a given amount of available heat in the hearth zone. If two fuels have the same indicated efficiency, or percentage of high temperature heat, and one produces a greater volume of waste gases per unit of available heat, its flow through the system will be faster and therefore it will tend to transfer its heat to the bath less effectively, to have a lower actual

TABLE X

RELATIVE VOLUME OF OUTGOING GASES

Fuel	Volume of products of combustion under standard conditions in cu ft per million Btu high temperature heat	
	20 ft checkers	12 ft checkers
Coke oven — blast furnace gas, premixed	18,200	22,200
Natural — blast furnace gas, premixed	19,800	.....
Oil	17,900	19,700
Producer gas + 10 per cent coke oven gas, premixed	19,000	21,300
Coke oven gas	18,900	21,000
Coke oven — blast furnace gas, not premixed	22,300	24,900
Producer gas	22,200	24,400
Blast furnace gas	33,000	.....

efficiency, and therefore either a lower steel producing rate or a higher temperature in the end and checker zones for the same production rate.

In Table X we list the volume of outgoing gases per million Btu of high temperature heat, for the various fuels, listed in the same order of decreasing efficiency as in Table IX. This gives another indication of the importance of efficient regeneration with premixed coke oven and blast furnace gas. With ordinary size checkers, this fuel has the same indicated efficiency as oil, but higher gas volume; whereas, with deep checkers, the efficiency is larger for the mixed gas and the gas volume about the same as for oil. Presumably then, from these static factors alone, the mixed gas would be a poorer fuel than oil or tar with average checkers, but somewhat better with very deep checkers.

Comparing the mixed gas premixed and not premixed, we find a gas volume of 18,200 and 22,300 respectively, which is one more advantage for premixing that will probably make the thermal efficiency difference in practice larger than indicated by Table IX. The decrease in "volume-burdening" obtained with the enriched over the straight producer gas should have a similar effect. The very large volume with blast furnace gas is probably one main reason for its ineffectiveness, as discussed above.

RELATIVE PEAK CHECKER TEMPERATURES FOR VARIOUS FUELS

In Table XI are listed values of relative peak brick temperature in the regenerative zone. Although some such temperature may well occur at certain points in the hotter portions of checkerwork, these values have no absolute significance; they are intended only to show the relative tendency toward overheating of top checker brick or downtake walls at comparable rates of burdening of the various fuels. They thus give some further insight into the advantage of various fuels with respect to hard driving, ease of checker cleaning, port end maintenance, etc. The peak temperature in gas checkers is lower for premixed blast furnace gas combinations than for the same fuels not premixed. All values are lower for premixed gases than for oil or coke oven gas. The levels in air checkers will be lower with the enriched than with straight producer gas.

DIVISION OF CHECKER AREA AND GAS FLOW WITH VARIOUS FUELS

In these calculations we have tried to divide the area

TABLE XI

RELATIVE PEAK TEMPERATURES OF BRICK

Fuel	Relative values of maximum brick temperature in hot end of regenerative zone			
	20 ft checkers		12 ft checkers	
	Air	Gas	Air	Gas
Coke oven — blast furnace gas, premixed	2160	2320	1860	2380
Natural — blast furnace gas, premixed	2160	2290	.....	....
Oil	2460	....	2370	....
Producer gas + 10 per cent coke oven gas, premixed	2355	2280	2260	2325
Coke oven gas	2460	....	2400	....
Coke oven — blast furnace gas, not premixed	2350	2530	2310	2480
Producer gas	2520	2240	2385	2250

TABLE XII

Fuel	Division of regenerators, per cent of perimeter for		Per cent of outgoing gases through each checker			
			20 ft checkers		12 ft checkers	
	Air	Gas	Air	Gas	Air	Gas
Coke oven — blast furnace gas, premixed	50	50	45	55	25	75
Natural — blast furnace gas, premixed	40	60	40	60	..	..
Oil	100	..	100	..	100	..
Producer gas — 10 per cent coke oven gas, premixed	60	40	55	45	45	55
Coke oven gas	100	..	100	..	100	..
Coke oven — blast furnace gas, not premixed	60	40	67	33	67	33
Producer gas	70	30	80	20	75	25
Blast furnace gas	50	50	38	62	..	..

of regenerator cross-section at each end in approximate accordance with the relative requirements for preheat between gas and air; the relative volumes of outgoing gases have also been divided approximately on the same basis. The values summarized in Table XII are not intended to be exactly the best in practice, but are good enough approximations to illustrate certain trends in furnaces properly designed for the several fuels.

In this respect those which are not preheated (oil, tar, coke oven gas, natural gas) have the advantage over the mixed fuels and producer gas. All the checker capacity is available for air preheating, and the total cross-section in furnace ends and downtakes is available for outgoing gases so that furnace design is simplified.

Nearly all the other fuels need divided checkers and downtakes, and such gas port design as will give sufficient direction and velocity to the flame. This last requirements makes the gas port a bottleneck in the system and introduces a contradiction between the dimensions needed for ingoing and outgoing gases. If the port is restricted enough to properly direct the flame it chokes the outgoing flow, so that either the gas port burns out too fast or too little flows out through the gas checkers.

With a furnace on premixed coke oven-blast furnace gas and deep checkers, the data indicate that gas and air checkers can be made the same size, with probably a little more than half the outgoing gases diverted to the gas checkers. This will be difficult with ordinary fixed port design. If water-cooled ports are used it will be necessary to provide sliding ports which move out and in upon reversal, also damper control in outgoing flues to apportion the gas flow as desired. Probably a better design is to use dry ports, with water cooled dampers between air and gas downtake (Brooke, J. B. R., Jour. I. and S. Inst. (British) 1936, II, 129-31) which open on reversal to by-pass the outgoing port. This allows of very little gas passing through the outgoing port so that it does not burn out and can be kept in shape without water cooling.

If the regenerators are of average size, the gas checkers apparently should be larger than the air checkers and should take 70-75 per cent of the outgoing gases. Such a design would probably be impractical; this again indicates the importance of deep, efficient regenerators in a mixed gas furnace.

Most furnaces using straight producer gas are built with about a 40:60 gas; air checker division, but our data indicate that this should be nearer 30:70 for best efficiency. With enriched producer gas the 40:60 division is correct, with about 45 per cent of the gases to the gas checkers if the regenerators are deep and efficient; this fuel might therefore be suited to the usual producer gas design with fixed ports, though it would be important to have damper controls and deep efficient regenerators, perhaps also a by-pass arrangement for gas ports.

With mixed gas, not premixed, with the coke oven gas injected at the ports and only the blast furnace gas preheated, the usual 40:60 gas: air checker division would seem suitable. The gas checker will run hot with only ⅓ of the outgoing gases to gas checkers. This is perhaps the one and only advantage of using mixed gas without premixing it, i.e., that it could be used on many old furnaces; it would give only moderate efficiency and probably a rather low producing rate, but might be applicable to many existing furnaces, provided the problem of rapid mixing and flame development in the port ends and of sufficient flame luminosity can be solved.

POSSIBLE PERFORMANCE OF MIXED GAS

As noted above, the only advantage of using a mixture containing blast furnace gas, without premixing, is that it might be used on older furnaces. With premixed gas it seems almost prerequisite that the furnace should be designed for this fuel, with extra large deep regenerators, and especially with larger gas checkers, with good damper control and some provision for conducting a large proportion of outgoing gases through these gas checkers.

In other respects the advantages are entirely with the premixed gas. Its theoretical thermal efficiency is much higher and it should be simpler to obtain a fairly luminous flame; also, the difficulty of poor flame direction encountered with straight coke oven gas should be much smaller. The data indicate that the performance of this fuel in a proper furnace is potentially equal to that of tar and oil; in fact, the maximum efficiency of mixed gas is the highest of any of the fuels. In practice this would be qualified by certain handicaps; on reversal

there is inevitably some 3-5 per cent loss of gas trapped in the regenerative zone, and more heat would be lost by water-cooled ports or by-pass dampers. Also, in operation with 30-35 per cent coke oven gas in the mixture during melting down at maximum fuel input, the port design would be such as to give good flame direction but without too much velocity or choke at the gas port; at certain stages of the heat, however, especially near tap, the heat input would have to be reduced materially to avoid overheating. This could, of course, be accomplished by cutting down the input rate of both coke oven and blast furnace gas, keeping the composition constant at what proves to be most efficient; but this method of adjustment would involve such a reduction in rate of input that proper flame direction might no longer be obtained. In practice, therefore, the temptation would be to adjust fuel input by reducing only the coke oven gas, keeping the rate of blast furnace gas constant. A large reduction in high temperature heat input would be obtained by this method with only a small reduction in total volume, and proper flame direction would be more easily maintained. With a convenient damper control, the proper thing would then be to divert relatively more outgoing gases to the air checkers as the proportion of coke oven gas is reduced, but at best such a procedure would give a lower thermal efficiency during such periods in the heat.

In certain other practical aspects the mixed gas has an advantage over tar and oil. As indicated above, the regenerative and end zone brick temperatures should be lower with mixed gas for equal rate of driving, and the carryover of dust and fume from the bath to slag pockets and checker brick might be less with the less concentrated flame zone. Cutting out of end walls and downtakes and clogging of checker openings might therefore be reduced and cleaning of checker work should be easier, so that driving the furnace toward its maximum production rates should be at least equally practicable. At all events, we can see that from the point of view of merely the static limitations, such premixed gas in a properly designed furnace is potentially capable of results comparing favorably to those with tar or oil.

The larger question of the economic advantage and the best overall allocation of by-product fuels in a steel works is much more complex, and is affected by engineering limitations of existing equipment. In this connection it should be kept in mind that, with respect merely to thermal economy, the enriched blast furnace gas mixture is peculiarly adapted to regenerative high-temperature furnaces. This is, therefore, some argument for allocating excess blast furnace gas mainly to the open hearth and using the remaining coke oven gas, coke breeze, etc., for reheating furnaces and boilers. It would be interesting to try to calculate the best overall fuel distribution in a plant layout with properly designed mixed-gas open hearths, thermally efficient soaking pits, reheating furnaces and boilers; the question would be, to what extent could such a layout be independent of all fuel except blast furnace coke and its by-product gases; also, whether it would then be advisable to put less emphasis on coke consumption in the blast furnace and to produce a larger excess of blast furnace gas.

APPENDIX A

THERMAL DATA AND EXAMPLE OF DETAILED CALCULATION

In these calculations the gases are assumed to be ideal, (disregarding the very small deviations present), the standard state is taken as 32 F or 492 absolute (T — Rankine scale) and one atmosphere pressure (= 29.92 in. mercury). In this ideal standard state the volume of the molecular weight in pounds of any of the gases is 359 cu ft.

All specific heats were calculated to the mean values over the temperature range desired. The heat capacity equations below are for the change of mean specific heat (S_M) per mole with temperature (T) in degrees F absolute; they are based on an equation for true specific heat (S) of the following form:

$$S = a + b \times 10^{-6}T + c \times 10^{-9}T^2.$$

For the temperature range T_1 to T_2

$$S_M = \int_{T_1}^{T_2} \frac{(a + b\times 10^{-6}T + c\times 10^{-9}T^2)dT}{T_2 - T_1}$$

or $S_M = a + \frac{b}{2}\times 10^{-6}(T_2 + T_1) + \frac{c}{3}\times 10^{-9}(T_2^2 + T_2T_1 + T_1^2)$

The constants in this equation in terms of Btu per lb of each gas are as given in Table A.

As an example, we may calculate the mean specific heat of 200 cu ft oxygen between 60 F and 2000 F. In terms of T° abs. this range becomes 60 + 460 = 520°T to 2000 + 460 = 2460°T. Since a lb-mol or 32 lb O_2 has a volume of 359 cu ft, 200 cu ft of O_2 weigh 200/359 = 17.82 lb. Then

TABLE A

Gas	a	b/2 x 10^{-6}	c/3 x 10^{-9}
O_2	0.1956	+23.8	—2.475
N_2	0.2250	+18.0	—1.27
CO_2	0.1556	+53.8	—5.78
H_2O	0.3828	+50.6	—1.96
H_2	3.44	+ 9.16	+14.35
CO	0.2235	+20.75	—1.687

TABLE B

Reaction	Heat of reaction (70 F) Btu per lb-mol of Compound
C (B graphite) $+O_2 \rightarrow CO_2$	+169,700
C (B graphite) $+1/2O_2 \rightarrow CO$	+ 47,800
$CO + \frac{1}{2}O_2 \rightarrow CO_2$	+121,900
$H_2 + \frac{1}{2}O_2 \rightarrow H_2O$	+104,000
$CH_4 + 2\ O_2 \rightarrow CO_2 + 2H_2O$	+345,000
$C_2H_4 + 2\ O_2 \rightarrow 2CO_2 + 2H_2O$	+577,000
$C_2H_6 + 3\frac{1}{2}\ O_2 \rightarrow 2CO_2 + 3H_2O$	+626,000
$CH_4 + CO_2 \rightarrow 2CO + 2H_2$	—106,200
$CH_4 + H_2O \rightarrow CO + 3H_2$	— 88,600
$CH_4 \rightarrow C + 2H_2$	— 32,300

$S_M = (0.1956 \times 17.82) + [23. \times 810^{-6} \times (2460 + 520) \times 17.82]$
$-[2.475 \times 10^{-9} \times (2460^2 + 2460 \times 520 + 520^2) \times 17.82] =$
$3.485 + 1.263 - 0.335 = 4.413$ Btu per °F.

Or, per unit volume, $\frac{4.413}{200} = 0.022$ Btu per cu ft

The heats of reaction given in Table B are convenient to use in fuel calculations; each is a net value with all products remaining in vapor state, and the plus sign denotes evolution of heat by the reaction as written.

For example, 25 cu ft methane reacting with CO_2 to form CO and H_2 will absorb

$$25 \times \frac{106{,}200}{359} = 7{,}400 \text{ Btu}$$

TABLE C

	Composition — Volume per cent — dry basis			Raw Mix cu ft		
	Coke oven gas	Coke oven gas simplified	Blast furnace gas	35 cu ft coke oven gas	65 cu ft blast furnace gas	100 cu ft raw mixture
CO_2	1.4	1.8	13.0	0.59	8.24	8.83
C_2H_4*	3.2	.....	.....	.....	.....	.....
CO	5.4	5.4	26.0	1.78	16.47	18.25
CH_4	28.7	36.7	0.5	12.06	.32	12.38
C_2H_6	0.8	.....	.....	.....	.....	.....
H_2	54.6	55.2	1.7	18.12	1.08	19.20
H_2S**	0.6	.....	.....	.....	.....	.....
N_2	4.9	4.9	58.8	1.63	37.30	38.93
H_2O	2.5	2.5	2.5	.82	1.59	2.41
Total	102.5	106.5	102.5	35.0	+ 65.0 =	100.0

* double and add to CH_4 ** add to H_2

TABLE D

	Coke oven gas			Blast furnace gas		
	Cu ft	Heat per cu ft	Btu	Cu ft	Heat per cu ft	Btu
C_2H_4	3.2 x	577,000 / 359 =	5,140			
CO	5.4 x	121,900 / 359 =	1,830	26 x	121,900 / 359 =	8,820
CH_4	28.7 x	345,000 / 359 =	27,580	0.5 x	345,000 / 359 =	480
C_2H_6	0.8 x	626,000 / 359 =	1,390			
H_2	54.6 x	104,000 / 359 =	15,800	1.7 x	104,000 / 359 =	480
			51,740			9,780
	51740 / 102.5 =	504 Btu per cu ft		9780 / 102.5 =	95 Btu per cu ft	

TABLE E

	Heat of reaction	
	Btu per mol	Btu absorbed per cu ft
(1) $CH_4 + CO_2 \rightarrow 2CO + 2H_2$	—106,200	265
(2) $CH_4 + H_2O \rightarrow CO + 3H_2$	— 88,600	245
(3) $CH_4 \rightarrow C + 2H_2$	— 32,300	90

TABLE F

	C lb	CO_2	CO	CH_4	H_2	N_2	H_2O	Heat absorbed Btu
		cubic feet						
In 100 ft³ raw mix there is:		8.83	18.25	12.38	19.20	38.93	2.41	....
Change by reaction (1)	.....	—6.30	12.60	—6.30	12.60	.....	.....	1865
Change by reaction (2)	.....	.....	1.80	—1.80	5.40	.....	—1.80	443
Change by reaction (3)	(+0.143)	.....	.....	—4.28	8.56	.....	.....	385
	(+0.143)	2.53	32.65 1.43	—	45.76	38.93	0.61	2693
To hearth per 100 cu ft of mixture	0.048	2.53	34.08	—	45.76	38.93	0.61	

TABLE G

	O_2 from air required	CO_2	H_2O	O_2	N_2	Air	Total Products
		cubic feet					
C 0.048 lb	1.44	1.44	.....	.....	.....	.....	.....
CO_2 2.53 ft³	.....	2.53	.....	.....	.....	.....	.....
CO 34.08 ft³	17.04	34.08	.....	.....	.....	.....	.....
H_2 45.76 ft³	22.88	.....	45.76	.....	.....	.....	.....
N_2 38.93 ft³	.....	.....	.....	.....	38.93	.....	.....
H_2O 0.61 ft³	.....	.....	0.61	.....	.....	.....	.....
121.91 ft³	41.36	38.05	46.37	.....	38.93	.....	.....
Air required	41.36	.....	2.80	.....	155.84	200	.....
10 per cent excess air	.....	.....	.28	4.14	15.58	20	.....
Total products, vol., cu ft	.....	38.05	49.45	4.14	210.35	....	301.99
Total products, weight, pounds	.....	4.64	2.47	0.37	16.35	.....	23.83

DETAILED CALCULATIONS FOR PREHEATED MIXED BLAST FURNACE-COKE OVEN GAS

Many of these calculations on the static limitations in the burning of this mixed gas in a sort of idealized open hearth are not necessarily directly applicable to practical open hearth fuel problems, yet the details may be of interest in the way of suggesting applications of analogous methods to more practical problems.

The general outline of the treatment of the properties of the mixture of 35 per cent coke oven — 65 per cent blast furnace gas has been given in the body of the report. We first assume the typical compositions as given in Table C and transform them to the basis of 100 ft³ of raw mixture before preheating.

The calorific value of the initial gas mixture, as calculated from the heat of reaction data in Table B, is given in Table D.

Therefore heat of combustion of raw mixture = 504 × 0.35 + 95 × 0.65 = 238 Btu per cu ft.

We next calculate to what extent each of the reactions shown in Table E must go to decompose all the CH_4 and yield 2.0 per cent CO_2 and 0.5 per cent H_2O by volume.

This last correction is on the assumption that ⅓ of the 0.143 lb of carbon is oxidized by FeO to CO, ⅓ remains as suspended particles, and ⅓ goes to the boiler. Thus 100 cu ft raw mixture becomes after it has been preheated and has reacted:

		Per cent by volume	Lb
C	0.048 lb	.....	0.048
CO_2	2.53 ft³	2.1	0.309
CO	34.08 ft³	28.0	2.650
H_2	45.76 ft³	37.5	0.254
N_2	38.93 ft³	31.9	3.030
H_2O	0.61 ft³	0.5	0.031
	121.91 cu ft	100.0	6.322

and its products of combustion (per 100 cu ft of raw mix) with air containing 20.6 per cent O_2, 1.4 per cent H_2O by volume are as given in Table G.

The heat capacity (S_M) per lb of the reacted gas between 60 and 2000 F (that is for T_1 = 500 degrees, T_2 = 2500 degrees approximately) is from the coefficients given in Table A.

We must take into account the heat absorbed by the reactions (1), (2), (3) as given in Tables E and F; we do this most conveniently by assuming that this heat absorption takes places over the same interval 60-2060 and so regarding it in effect as an added heat capacity term whose value is 2693 ÷ 2000 = 1.347 Btu per degree for 121 cu ft, or 0.011 per cu ft reacted gas per degree. Thus the total heat capacity of the reacted gas is

TABLE H

	C	CO_2	CO	H_2	N_2	H_2O	O_2
a	....	0.1556	0.2235	3.440	0.2250	0.3828	0.1956
$b/2 \times 10^{-6}$	....	.1615	.0623	.027	.0540	.1520	.0714
		.3171	.2858	3.467	.2790	.5348	.2670
$c/3 \times 10^{-9}$		—.0448	—.0131	+ .111	— .0100	— .0152	—.0192
S_M, Btu per lb	0.4	.2723	.2727	3.578	.2690	.5196	.2478

	Weight, lb		S_M, Btu per lb		Heat capacity
C	0.048	x	0.4	=	0.0192
CO_2	0.309	x	0.2723	=	0.0843
CO	2.650	x	0.2727	=	0.7240
H_2	0.254	x	3.578	=	0.9080
N_2	3.030	x	0.2690	=	0.8160
H_2O	0.031	x	0.5196	=	0.0161
					2.5676 for 121.9 cu ft
					0.0211 Btu per cu ft per °F

TABLE J

	Weight, lb (Table G)		S_M Btu per lb		
CO_2	4.84	x	0.3011	=	1.395
H_2O	2.47	x	.5708	=	1.410
O_2	0.37	x	.2012	=	0.096
N_2	16.35	x	.2847	=	4.660
	Total for 302 cu ft			=	7.561 Btu per F
	= 0.0250 Btu per cu ft per °F between 2600 and 700 F				

0.011 + 0.021 (from Table H) or 0.0321 Btu per cu ft per degree.

We likewise need the heat capacity of the gaseous products over the range 2600-700 F (that is $T_1 = 3100$, $T_2 = 1200$), this being the assumed temperature range in the checkers; because of this difference in range, the values differ somewhat from those in Table H; the details of the calculation of S_M are omitted from Table J.

A similar calculation for the range 2860-60 F gives the figure 0.0242; and by combination of the data in Table H, the heat capacity of air in the range 60-2060 F is 0.0212 Btu per cu ft. or 0.797 Btu per lb.

The calorific value of the reacted gas, from the weights given after Table F, is as calculated in Table K.

On the basis of the values just calculated, the estimated flow rate required to yield 17 x 10-6 Btu per hr of high temperature heat is as set forth in Table L.

The velocities in the last two columns above are calculated on the basis that 57 per cent of the outgoing gases pass through the gas checker, 43 per cent through the air checker; that the cross section at each end is divided equally between gas and air and the depth is 20 ft.

These are the mean linear velocities of gas flow through an assumed checker with 73.5 sq ft of free area with the gas under standard conditions. In actual checkers the gas is at variable temperature and velocity, so it is simpler to convert all heat transfer data to gas velocities under standard conditions, and then to correct for the mean temperature. We assume that the products of combustion enter the checkers at 2600 F and leave at about 900 F, so the mean temperature is around 1700-1800 F. Mixed gas is assumed to be preheated to 2000 F and its mean temperature is therefore 1000-1100 F. We find the following heat transfer coefficients, (the coefficient for air depends only on velocity), in terms of Btu per sq ft of brick surface exposed to gases per hour per degree F temperature difference between brick and gas:

	Heat transfer coefficient
Products — air checker	4.6
Air — air checker	2.4
Products — gas checker	5.0
Mixed gas — gas checker	3.0

This completes the essential thermal data which determine the efficiency of preheat in the regenerators.

TABLE K

	Pound-mols		Btu per lb mol (Table B)		Btu
$C \rightarrow CO_2$	$\frac{0.048}{12}$	x	169,700	=	678
$CO \rightarrow CO_2$	$\frac{2.65}{28}$	x	121,900	=	11,550
$H_2 \rightarrow H_2O$	$\frac{0.254}{2}$	x	104,000	=	13,200
					25,428 for 121.9 cu ft
				or =	210 Btu per cu ft per °F, whereas
				that of the raw mix (Table D) =	238

TABLE L

	Relative volume	Cu ft per hr	Cu ft per sec	Velocity — (ft per sec) in Gas checker	Velocity — (ft per sec) in Air checker
Raw mix	100	105,000	= 29.2	$\frac{32.3}{73.5 \times 0.5} = 0.9$	
Reacted gas	121.9	128,000	= 35.5		$\frac{55.6}{73.5 \times 0.5} = 1.5$
95 per cent of combustion air	190	200,000	= 55.6		
Gaseous products	302	317,000	= 88.1	$\frac{88.1 \times 0.57}{73.5 \times 0.5} = 1.4$	$\frac{88.1 \times 0.43}{73.5 \times 0.5} = 1.0$

TABLE M

	Per cent of temperature range: Beginning of cycle	Per cent of temperature range: End of cycle	Average	Equivalent Average °F
Mixed gas after passing checker	77.2	74.0	75.6	1980
Gaseous products leaving gas checker	29.8	34.0	31.9	870
Air after passing checkers	64.7	60.7	62.7	1655
Gaseous products leaving air checker	23.4	21.4	22.4	630
Top courses brickwork — air checker, peak temperature			89.0	2320
Top courses brickwork — gas checker, peak temperature			82.5	2160

We now transform these data into equivalent electrical values of resistance and capacity, and make the corresponding calculations for checker efficiency on air and gas using the electrical analogue as the calculating machine. This gives us results (See Table M) in terms of percentage of the regenerator temperature range, which we have assumed to be from 60 F incoming cold air temperature to 2600 F, the assumed "equivalent top temperature" of hot gases to the regenerative zone; (the equivalent F values are also included).

These data now comprise all the thermal values needed for the calculation of "high temperature heat" given previously in the body of the paper. Similar methods were used for calculations on the other fuels, being in most cases somewhat simpler than the above because reactions occurring in the mixed gas in the regenerators were not involved and, in the case of oil or coke oven gas, because there are no gas checkers.

DISCUSSION

PRESENTED BY

J. S. MORRIS, Engineer, Lukens Steel Company, Coatesville, Pennsylvania.

A. J. FISHER, Fuel Engineer, Bethlehem Steel Company, Sparrows Point, Maryland

R. R. FAYLES, Assistant to Open Hearth Superintendent, Lukens Steel Company, Coatesville, Pennsylvania

B. M. LARSEN, Research Laboratory, United States Steel Corporation, Kearny, New Jersey

J. S. Morris: The point that Mr. Larsen brought out very well is the effect the depth of an open hearth

checker system has on the efficiencies of the fuel burned. The data also give us a good idea as to why some plants work better on mixed gas fuels than others, simply because the checker volume is divided between air chamber and gas chamber more favorably for the most efficient preheating of the gas and air.

A. J. Fisher: Mr. Larsen's comparisons are very interesting. I might say, in connection with fuel oil, that we at Sparrows Point have gone into longer checker travel than Mr. Larsen has indicated. He shows 20 ft travel of checkers. Our maximum depth in the two-pass checker system is 17 plus 17, or about 34 ft.

The heart of the furnace is in the regenerators, and length of travel is very important. On new furnaces, when the checkers are clean and efficient, we have developed flame temperatures in excess of good refractory working conditions. In other words, we have reached the refractory limitation and the fuel in the furnace has to be reduced because of this refractory limitation. So the only thing that can be done in that case is to put in an excess amount of air to reduce the temperature of the air preheat and to bring it back within range of the refractories. The practical limit, therefore, is about 34 feet travel for oil.

Going a step farther, you can well imagine that the efficiency in the bath is a function of how much heat you take out of the flame at the various stages of that bath. For instance, if you were able to take all the heat out in the first stages or the first part of the flame, the furnace, being a heat exchanger, would have its maximum efficiency irrespective of the total amount of heat put in. If you were able to take no heat out of it above the hearth, your efficiency would be zero. What are the factors enabling you to get heat out of the flame? The factors are carbon radiation. In oil flames, you will find that the more free carbon that you can put in the flame, the more heat you can radiate in the early stage of the flame, thereby increasing the efficiency of the furnace.

Of recent date, we have received all kinds of fuel oil — and we are glad to get them, too, by the way, if and when we can — and these various grades that we get are anything from kerosene to what we might call "heavy" oil. We know that the light oils do not burn as well as heavy oils under the same conditions. We believe burners could be designed to give the same radiating effect with light oils as with heavy oils, but inasmuch as the oils do vary, we hate to take a chance of designing for one oil in fear of getting the other. So we strike a happy medium.

A great amount of interest has been shown here lately in stabilizing the carbon content of fuel oil by carbon additions in the form of pitch, lampblack or finely ground coal, say 325 mesh or finer, even up to the point where it is held in colloidal suspension. It seems that one of the future problems of the open hearth is to be able to make a standard fuel with a fixed carbon content.

It would be very desirable to stabilize the ordinary grades of oil as they come in, say at a pitch value which is high in carbon — and, by the way, the people burning tar and pitch seem to do better than those burning heavy oil, when the burners are designed for pitch.

We might reflect on another development which is on the horizon, that is, supersonic oil atomization, in which the oil particles are broken up by high frequency sound waves into their molecular constituents. Oil can be mixed with any gas — blast furnace gas, coke oven gas and so on — and that, apparently, opens up another new field for open hearth fuels.

It is very easy to imagine a fuel like coke oven and blast furnace gas being mixed together to give the right physical characteristics in the open hearth. We know coke oven gas alone is too light and goes up and burns the roof, and has no luminosity at all, whereas blast furnace gas is heavy, has a high specific gravity, and would tend to remain on the hearth. If you could mix these two fuels in the various physical proportions so they would lie along the bath properly, and add the correct amount of carbon, an ideal flame would result. There are many potential aspects to this open hearth fuel problem.

R. R. Fayles: I would like to point out that the open hearth is a metallurgical furnace as well as a fuel-burning furnace. While we might try to approach Mr. Larsen's theoretical efficiencies, there are many operating problems which make it extremely difficult to burn fuel at its peak efficiency. Of course, we use 100 per cent cold charge at Lukens, not having hot metal available. In our high scrap practice, we find it necessary to run fairly long and inefficient flames at times in order to combat certain metallurgical conditions that arise within the bath.

I was interested in Mr. Fisher's comments on 34-foot checkers. I wondered if he also considers the effective regenerative volume, as well as the depth of checkers and the length of flame travel. It is generally good practice to have two-pass checkers such as he has, but it is also necessary to take advantage of the full checker width so that "channeling" does not affect the total heat transfer.

B. M. Larsen: Just a couple of items: The 20-ft checker depth involved in these tables would really be equivalent to a deep two-pass regenerator on the size furnace that Mr. Fisher was talking about. With maybe an 18 or 20 foot depth, in each pass, it was a checker approximately equivalent, probably, to the new Sparrows Point shop, if made with two-pass design to minimize channeling.

We did find in various subsidiary calculations a very serious effect from channeling. It is interesting to note that the effect of channeling is minimized somewhat by the fact that the outgoing gases can radiate heat as they pass over near the bridge wall. Even though the gases do not flow down through the first flues, they can transfer heat by radiation, so you get some correction of the channeling effect.

I suppose you know that the effect of channeling (as we have found in practice in badly designed furnaces) is that the outgoing gas tends to smash over toward the far end of chamber and the air beneath tends to shoot through to the inner end; in an extreme case you would not get much heat regeneration at all. Actually we find some of that effect in some of the older furnaces and no doubt the two-pass design, or anything that will make the channeling less, is an important factor in regenerator design.

We found in some studies on luminosity that the best results seem to be obtained with a flame extending over

(*Please turn to page 115*)

BRENT WILEY

T. J. ESS

Association of Iron and Steel Engineers Changes Managing Directorship

Brent Wiley, managing director of the Association of Iron and Steel Engineers since 1936, has resigned this position, effective January 1, 1946. He will continue to be identified with the Association as an advisory consultant.

A graduate of Rose Polytechnic Institute in electrical engineering, Mr. Wiley first worked for Carnegie Steel Company at the Ohio and Homestead works. In 1904 he went with Wellman-Seaver-Morgan Company as electrical engineer, and in 1906 became associated with Westinghouse Electric and Manufacturing Company, where he spent the next 25 years. With this company he was closely allied with the developments of electrification in the steel industry.

This industrial background gave Mr. Wiley a keen appreciation of the Association's work in the advancement of engineering in the steel industry, and enabled him to guide the Association in the pursuance of its aims. During the ten years of his managing directorship, the Association has developed materially in membership and strength, and has broadened considerably in the scope of its activities. During this period, the Detroit and Buffalo district sections were established, and the Rolling Mill Committee of the Association was formed. Mr. Wiley was deeply interested in establishing and revising standard specifications for various items of steel plant equipment, in furthering the educational work of the Association, and in increasing its service to the industry.

To succeed Mr. Wiley as managing director, the Board of Directors has elected T. J. Ess, who has been connected with the Association since 1938.

Following graduation from Carnegie Institute of Technology in mechanical engineering, Mr. Ess spent 15 years with Republic Steel Corporation and its predecessors, Central Steel Company and Central Alloy Steel Company, in maintenance, power and combustion work. He then joined the Association staff in an editorial capacity and has more recently assumed general supervisory work. He is editor of "The Modern Strip Mill" and the author of many articles in the Iron and Steel Engineer.

Aluminum Bronze Welding

IN STEEL PLANT MAINTENANCE

. . . . aluminum bronze alloys, which have proven themselves in parts of equipment subject to wear or corrosion, have equally valuable maintenance applications as coated electrodes for metallic arc, carbon arc and oxyacetylene welding . . . .

by F. E. Garriott

DEVELOPMENT MANAGER

AMPCO METAL, INC.

MILWAUKEE, WISCONSIN

▲ THE tonnage of steel produced and processed through a steel mill, rated against nominal capacity of that mill, is indicative of its efficiency. In fact, the success of individual departments and supervision within the mill is gauged with reference to output in number of tons per day or month.

The amount of billet, plate or sheet passing through the rolling mills is directly proportional to the operating time. Due to wartime conditions, mills must operate at high rates of speed twenty-four hours per day. Naturally, the higher the speed of production, the greater will be the wear on the component parts of the machinery and resultant down-time. Any means of increasing productive time and reducing down-time in a steel mill is desirable because it not only reduces maintenance costs but results in a higher yield and increased earnings to the operating personnel.

Within recent years, the practice of surfacing machine parts subjected to excessive wear, abrasive and corrosive action by means of the metallic arc, carbon arc and oxyacetylene welding processes has received wide acceptance throughout industry. Today, it is common practice in the steel industry to design parts of new equipment with wear and corrosion resistant alloys on the surfaces subjected to excessive abrasion and where adequate lubrication is impossible or difficult to apply. Heretofore, surfacing of machine parts has been used primarily for maintenance applications and in this field, it still remains of great importance.

Maintenance cost is of necessity the main item of consideration in selecting the type of weldrod and the method of applying wear-resistant surfaces to equipment parts of any kind. In any machine operation, failure of parts means enforced idleness of the machine and crew. Repair cost, then, includes not only the cost of the new part and replacement costs but also loss of productive time while repairs are being made. Often loss incurred by idleness of the machine is greater than the total repair cost. It is impossible to design and construct a machine that will operate continuously without repairs, but through the proper selection of alloy overlays on wearing parts, the periods of operation between repairs can be greatly increased.

It is usually good practice to resurface parts of machinery several times after they have become worn in service. Frequently, this may be done at less expense than the replacement cost of new parts since the life expectancy of many surfaced parts is 5 to 25 times that obtained with a new replacement part. Where a part is resurfaced several times considerable savings result

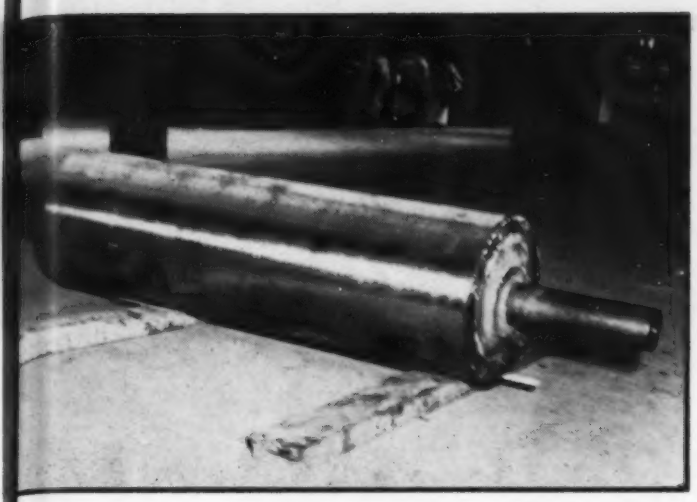

Figure 1 — Tin plate scrubber rolls, fabricated with grade 3 electrodes from centrifugal aluminum bronze castings.

Also, cheaper materials such as low carbon steels, etc. may be successfully substituted for more expensive alloys when the surface of those lower cost materials is overlayed on wearing areas. This results in better service at a much lower initial cost.

ALUMINUM BRONZE ALLOYS

Aluminum bronze alloys have been used for many years in steel mills for dies, guides, slides, screw down nuts, bushings, gears, pickling baskets and other equipment subject to wear or the attack of corrosive media where other alloys have failed under severe service conditions.

Aluminum bronzes are copper base alloys containing from 5-14 per cent aluminum and up to 5 per cent of iron. Some variations also contain additions of nickel and manganese. However, the copper-aluminum-iron alloys will be the basis for discussion in this paper.

In general the outstanding characteristics of the aluminum bronzes in comparison to other bronzes are:

1. Higher tensile strengths (65,000-110,000 psi)
2. Higher yield strengths (30,000-70,000 psi).
3. Higher ductility (tensile strength ratios)
4. Higher impact strengths, enabling the alloys to withstand shock loading.
5. Higher fatigue resistance.
6. Controllable hardness through a range of from 115 to 300 Brinell.
7. Retention of physical properties at sub-zero temperatures.
8. Good retention of properties at elevated temperatures up to 750 F.
9. Good bearing qualities.
10. Corrosion resistance to a wide variety of corrosive media.
11. Response to heat treatment.
12. Lower weight compared to other bronzes and brasses.
13. Higher strength-weight ratios.
14. Weldable by most welding processes.

The hardness of aluminum bronzes and aluminum bronze welding electrode deposits increases directly with the increase in the aluminum and iron content of the alloy. Aluminum is the primary hardener although iron does have a slight hardening effect. However, iron additions to the alloy are usually made in order to improve the grain structure.

Aluminum bronzes with 9.5 per cent aluminum content and less are alpha phase alloys which are soft and ductile. They do not respond to heat treatment. As the aluminum content increases, the alloys become increasingly harder and less ductile. These alloys do respond to heat treatment due to the development of the harder constituents such as delta, beta and eutectoid in varying amounts depending upon basic composition and the cooling rate through the critical temperature ranges.

Within recent years, these alloys have been made available to welding engineers, designing engineers and shop maintenance departments in the form of coated

Figure 2 — Cast steel ram from 125 ton riveting press, overlayed with grade 2 aluminum bronze electrodes.

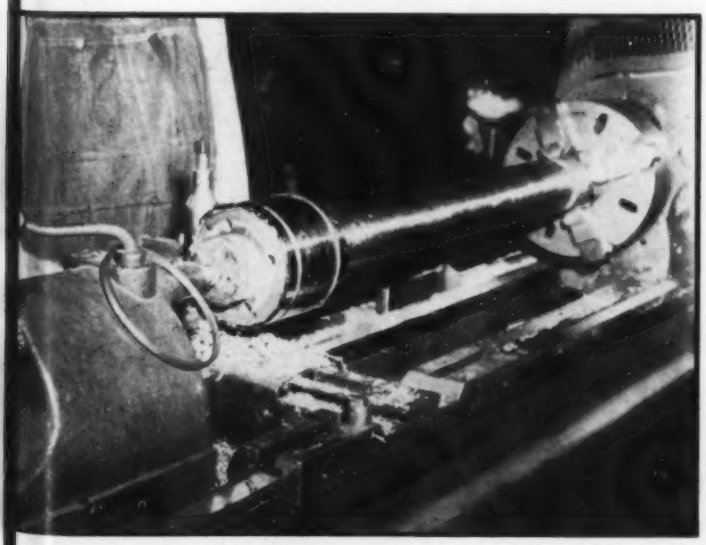

Figure 3 — Pipe mill arbor shoes, with bearing surfaces overlayed with grade 4 aluminum bronze electrodes.

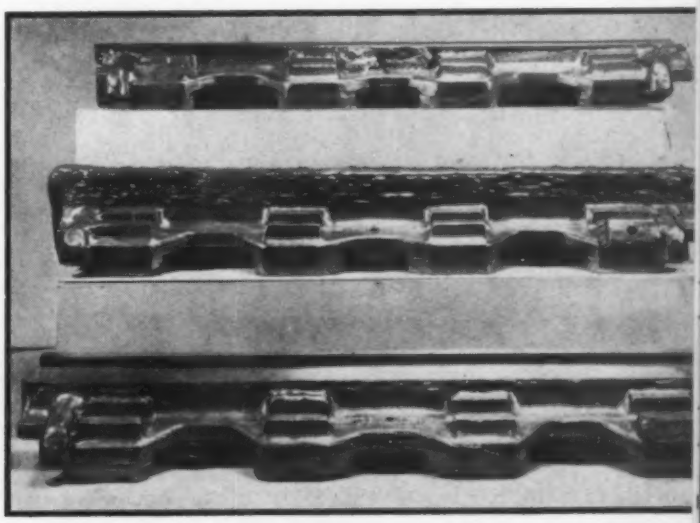

TABLE I

CHEMICAL COMPOSITION OF ALUMINUM BRONZE ELECTRODE WELD METAL

Grade	Aluminum per cent	Iron per cent	Silicon per cent maximum	Other Elements maximum per cent, each	Copper
1	7.0 — 9.0	0.5 — 1.5	1.0	0.6	Remainder
2	8.0 — 10.0	0.5 — 5.0	1.0	0.6	Remainder
3	9.0 — 11.0	3.5 — 6.0	1.0	0.6	Remainder
4	10.0 — 13.0	3.5 — 6.5	1.0	0.6	Remainder
5	12.0 — 14.0	4.0 — 6.5	1.0	0.6	Remainder

TABLE II

AVERAGE ALL WELD METAL PHYSICAL PROPERTIES OF ALUMINUM BRONZE ELECTRODES*

Grade	Base material	Ultimate tensile strength, psi	Yield point psi	Per cent elong. 2 in.	Per cent reduction of area	Hardness Brinell** 3000 kg load
1	SAE 1020 Steel	91,000	43,000	27.0	26.0	120
	Aluminum Bronze	77,000	35,000	27.0	27.0	119
	Manganese Bronze	68,000	35,500	21.0	23.0	121
2	SAE 1020 Steel	97,000	41,000	19.0	21.0	160
	Aluminum Bronze	89,000	47,000	15.0	17.0	177
3	SAE 1020 Steel	101,000	40,000	9.0	17.0	200
	Aluminum Bronze	90,500	46,000	4.0	5.0	212
4	SAE 1020 Steel	86,000	45,000	1.5	3.0	250
	Aluminum Bronze	77,000	54,000	1.0	0.0	260
5	SAE 1020 Steel	73,000	55,000	0.5	0.0	300
	Aluminum Bronze	80,000	69,000	0.5	0.0	316

*Metallic arc process
**Pad weld hardness values

welding electrodes that are used for metallic arc, carbon arc and oxyacetylene welding applications.

The unusual combination of desirable properties inherent in aluminum bronze alloy castings, plate, sheet and extruded shapes is thus further extended to industry in the weld deposits produced by these weldrods.

Until the aluminum bronze electrodes were introduced, there were no high strength bronze welding electrodes available with equivalent physical properties for welding the high strength brass and bronze cast and wrought alloys used industrially for many years.

Aluminum bronze electrode core wires do not contain zinc which is, generally, a principal constituent of other high strength bronzes or brasses and which volatilizes readily in the arc. Joint and overlay weld deposits made with aluminum bronze electrodes are free from porosity and surface pitting and have high strength, high hardness and good ductility when welding the high-zinc copper alloys.

Five grades of aluminum bronze welding electrodes are available for fabrication and maintenance welding applications. They vary in alloy composition and, therefore, in physical properties and cover a wide variety of service requirements. In Table I, the types are listed with reference to average deposit analyses taken from pad welds made on SAE 1020 steel plates following accepted Army-Navy test procedures.

Physical properties of all-weld metal deposits vary with the type of base plates used due to dilution from the parent metal. In Table II all-weld metal physical properties are given for deposits of grade 1 electrodes on mild steel (SAE 1020), manganese bronze and a matching grade of aluminum bronze plates. The all-weld-metal physical properties of the harder grades are given in mild steel and matching grades of aluminum bronze plates.

It should be noted that as the aluminum and iron contents of the alloy electrode deposits increase, the deposit hardness increases proportionately.

The Grade 1 electrode is generally used as a joining electrode since it combines high strength with excellent ductility. This type of electrode is outstanding due to the fact that it can be used to weld dissimilar metals. It will successfully weld steels, copper, bronze, brass, cast iron, malleable iron, nickel alloys, high manganese steels, etc. This electrode can also be used for overlays where a comparatively soft deposit is sufficient for the service required.

The other four grades are recommended, generally,

for overlay work for more severe wear and corrosion resistance service.

In most welding applications, the use of the metallic arc process is to be preferred and used wherever possible since it is the most economical and most rapid method of applying weld deposits.

WEAR RESISTANT QUALITIES

The harder grades of aluminum bronzes are used extensively in place of hardened tool steel and cast iron for drawing and forming dies especially where improved appearance of the product is desirable. These alloys are particularly applicable for use in the drawing and forming of stainless steel sheet products.

The success of aluminum bronzes in these die applications is due to a combination of desirable properties including high hardness, good wear resistance, unusual antifriction characteristics and resistance to high compressive loads. Dies made from these alloys often require less frequent redressing than do steel dies for the same service because there is no tendency to "load" which results in galling.

Figure 5 — Overhead crane rail repaired with grade 1 aluminum bronze electrodes.

▲

Figure 6 — Stainless steel parts drawn over aluminum bronze dies.

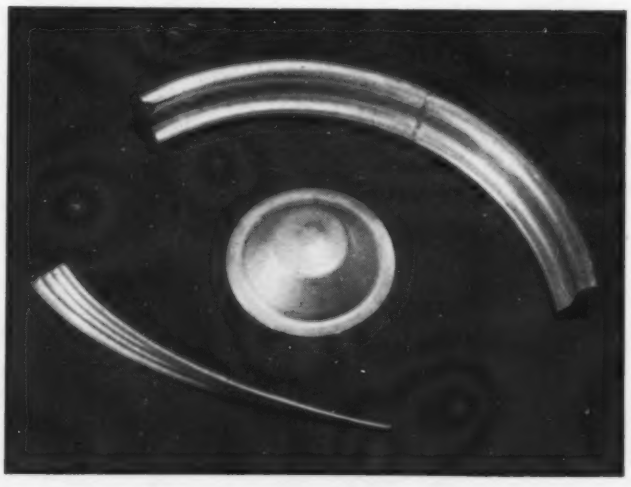

Figure 4 — Bronze bushing and mild steel flange welded with grade 1 aluminum bronze electrodes.

Aluminum bronze electrodes are used for repair welding of these dies as well as the surfacing of new steel dies and the reclamation of worn steel and cast iron dies. Grade 1 is generally used for spot repairing of cracks in hardened tool steel dies while Grade 4 is the type of electrode recommended in overlaying large steel dies for drawing stainless steel.

Cast bronze guides have been used in steel strip mills for many years since a dissimilar metal is required to avoid scratching of the sheets and pick-up of the guide material onto the steel sheet.

In the past, these guides have been resurfaced with phosphor bronze or other soft bronze deposits applied by means of the carbon arc welding method. The resurfaced guides on the outlet side of a continuous cold reduction mill producing at the rate of 800 fpm of .0625 in. and lighter sheets have a service life of from four to eight hours.

This guide service life has actually been increased from an average of six hours to twenty-four hours by using metallic arc overlay deposits of aluminum bronze electrodes of the grade 5 type due to increased deposit hardness and wear resisting properties.

Arbor shoes in pipe mills wear rapidly and require frequent redressing. Overlays on the bearing surfaces with grade 4, aluminum bronze electrodes actually give better service than the original casting.

HIGH STRENGTH WELDED JOINTS

Grade 1 aluminum bronze electrodes have been used extensively to arc weld joints in overhead crane rails. Joints in new rails are welded in order to obtain a continuous smooth surface without joint openings. Joint openings are objectionable because they cause flat spots and rail misalignment, which result in undue wear and maintenance on the equipment operating over the rail as well as the rails themselves.

For overlaying worn rail ends, the grade 3 aluminum bronze electrode is recommended since the higher hard-

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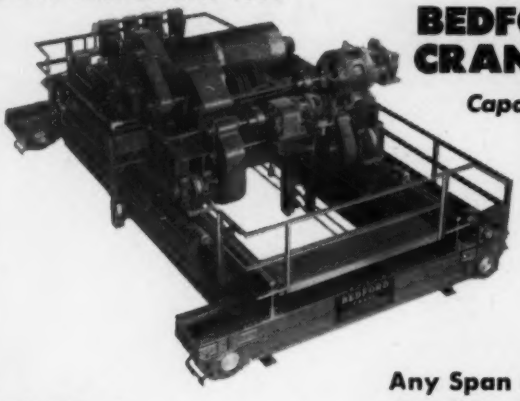

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Figure 7 — Aluminum bronze pickling basket fabricated by welding.

ness values obtained in the weld deposit resists wear more readily than the softer grade which is primarily recommended for joint welds in metals difficult to weld.

CORROSION RESISTANCE

Corrosion is a problem in any steel mill. Hundreds of thousands of dollars are lost annually in industry due to the effect of corrosion upon metals and through the improper selection of materials for specific applications. Aluminum bronzes effectively resist the corrosion of a wide variety of corrosive media outstanding among which are sulphuric acid pickling solutions.

Pickling baskets fabricated by welding have given excellent service in sulphuric acid solutions. Broken pickling stems and various other worn parts in this type of service have been repaired and builtup with grade 3 aluminum bronze electrodes.

Other steel mill applications for aluminum bronze electrodes are the building up of gear teeth, up-set machine wedges, slipper segments, wear strips, copper conductor bars, hanger yokes, bushings, hairpin hooks, slides in nail and bolt heading machines, hydraulic ram heads, etc.

Aluminum bronze electrodes, due to an unusual combination of inherent properties, including high tensile strength, hot ductility, wear and impact resistance, controllable hardness, corrosion resistance, etc. open up new fields of welding to the welding engineer. Maintenance engineers and superintendents will find many applications in the repair welding of plant equipment where aluminum bronze electrodes will produce results never attained before with other types of electrodes.

The iron and steel industry is only one of the major industries where aluminum bronze and aluminum bronze welding electrodes are playing an outstanding role in the solution of maintenance and production problems today. There are just as many or more applications for these alloys in other industries, such as automotive, shipbuilding, machine tool, coal mining, sugar, excavating, utilities, railroads, etc.

THE *Flash Welding* OF STEEL

. . . . improvements in flash welding have been particularly striking . . . . this paper sets forth the principles of flash welding and illustrates their applications to modern production problems . . . .

by J. C. Barrett, METALLURGIST

THE TAYLOR-WINFIELD CORPORATION

WARREN, OHIO

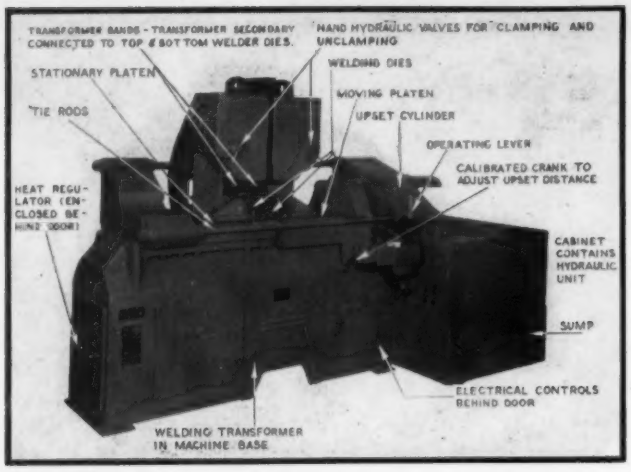
▲ KNOWLEDGE of the metallurgical and electrical principles involved in the flash welding of steels has grown rapidly in recent years, particularly in the field of alloy steels. Hand in hand with this technical advance have appeared many new industrial applications of flash welded parts. Highly stressed assemblies, made from high strength alloy steels, are fabricated by the flash welding process; steels of widely different chemical compositions are welded together for certain uses; intricate parts of many shapes are joined by this method, with a saving in cost of forging, drawing, or machining. The problems of warfare have given an added impetus to the flash welding art, an impetus that should carry it well into the field of peacetime pursuits.

In this paper a few of the numerous applications of flash welding will be described, together with some of the metallurgical problems encountered in making these applications successful.

THE PROCESS

First let us consider the flash welding process itself. This process is one of the types which comes under the general head of electrical resistance welding. In flash welding, the two parts to be welded are rigidly clamped in pairs of conducting dies, one pair of which is connected to a stationary, the other to a movable, platen. With the current on, the two pieces to be welded are brought together by advancing the movable platen. When slight contact is made, the current flowing from one piece to the other causes a heating action at the butting faces. This current is carried by a number of small contacts between the two pieces. These small contacts, or bridges are rapidly heated to incandescence, become molten, and are blown from the butting faces in a shower of sparks because of the strong magnetic field surrounding the welder. The movable platen continues to move toward the stationary platen, and the series of small molten bridges continues to blow out. This is called the "flashing period," during which time the butting pieces are being brought to the welding heat. When the pieces, by virtue of the flashing action, are deemed to be at the proper temperature, the movable platen is suddenly accelerated, and the two pieces are butted together under high pressure. This forging action, or upset, completes the weld. Naturally that portion which has been upset increases in section due to forging. The two pieces being welded are backed up, so that the dies do not have to take all the upset force. Theoretically all molten metal, slag and oxides present on the flashing surfaces just prior to upset are extruded into the flash

Presented before A. I. S. E. Detroit District Section Meeting, April 10, 1945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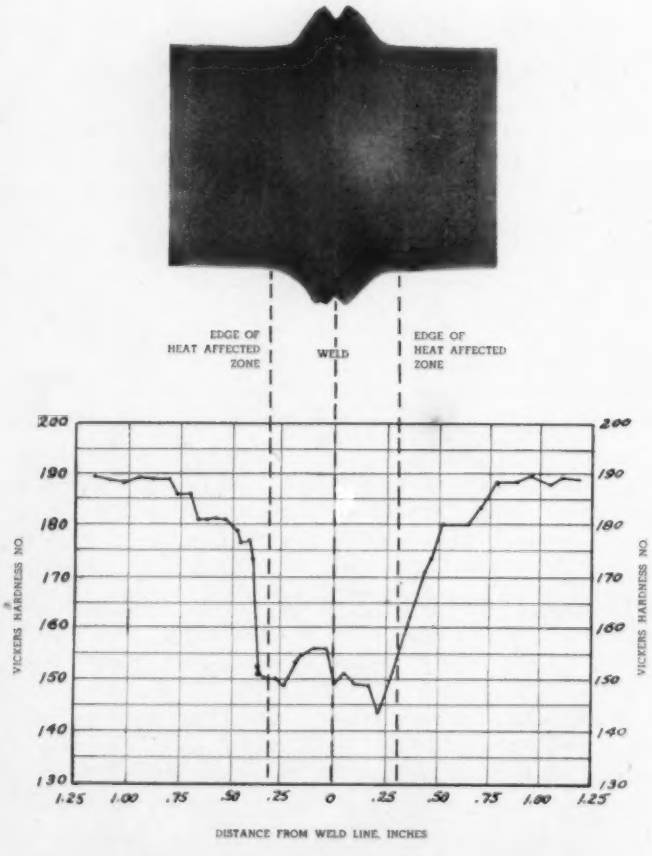
HEAT REGULATOR (ENCLOSED BEHIND DOOR)
CABINET CONTAINS HYDRAULIC UNIT
SUMP
ELECTRICAL CONTROLS BEHIND DOOR
WELDING TRANSFORMER IN MACHINE BASE

Figure 1 — Hydraulic butt-flash welder with vertical hydraulic clamping fixture.

or upset material, providing a sound weld of a composition close to that of the welded pieces. As there is no filler metal and no cast nugget, as in arc or spot welding, it is possible, again theoretically, to obtain a weld which, after proper heat treatment, has the same properties as the parent material.

Figure 2 — Photomacrograph and Vickers hardness plot across a flash weld in 1 in. diameter low carbon, cold rolled steel. Specimen etched in 4 per cent nital. Hardness values plotted across the center of section.



In Figure 1 is shown a flash welding machine of the hydraulic type, with all parts designated.

GENERAL METALLURGICAL CONSIDERATIONS

Since the pieces are heated during flashing, and since this heat is localized between the dies, there is always a temperature gradient existing from the highly heated flashing surfaces back to the cold dies. This gradient gives rise to a succession of metallurgical changes. In Figure 2 is seen a photomacrograph of a flash weld in low carbon cold rolled steel, together with its Vickers hardness plot. The weld, heat affected zone, and upset material can be easily seen.

These three parts of the welded piece are within the area which was heated during welding to temperatures above the lower critical point. These are soft in cold rolled steel because the effects of cold rolling have been obliterated by transformation and recrystallization. Between the heat affected zone and the parent metal, there is a zone increasing in hardness as one goes further from the weld, until the parent metal hardness is reached. This zone is that in which the temperature was below the lower critical but was high enough to cause recrystallization and relief of cold work.

A weld in this material would not be heat treated after welding. Not only is the change in hardness not great, but any heat treatment applied would only serve to soften the parent metal. The hardness plot of a flash welded low carbon hot rolled steel would be even more uniform than that in cold rolled steel, since the only difference would be in a lower hardness of the parent metal of the former. No heat treatment, then, is necessary for flash welds in low carbon steel, unless for certain effects, such as a uniform grain size.

In contrast, consider Figures 3 and 4, which are photomacrographs and hardness plots of two alloy steels. In Figure 3 is shown a weld in a 1 in. diameter chromium-nickel-molybdenum steel bar of about .30 per cent carbon; in Figure 4 a weld in a 1 in. diameter SAE 2315 steel bar (3½ per cent nickel, .15 per cent carbon). Both welds are characterized by the following:

1. The heat affected zone is of a distinctly different structure than the parent metal, and has different appearing zones within itself.
2. The hardness of the heat affected zone is higher than that of the parent metal.
3. The weld line is lighter in color than the areas on either side, due to the loss of carbon at the surfaces during flashing.
4. The hardness of the weld line is lower than that of the areas on either side, again due to the lower carbon content of the weld line.

These steels are air-hardening, the first (Cr-Ni-Mo) markedly so, because of its higher carbon content and its chromium and molybdenum content and the second moderately so, because of its lower carbon content. This is reflected in the hardness plots. Because of the heat conductivity of the copper dies and that of the cold steel back of the heat affected zones, these welds cooled at a much faster rate than if they had received a simple air cool.

In alloy steel flash welds, as well as in hardenable carbon steel welds, then, if one wishes to have uni-

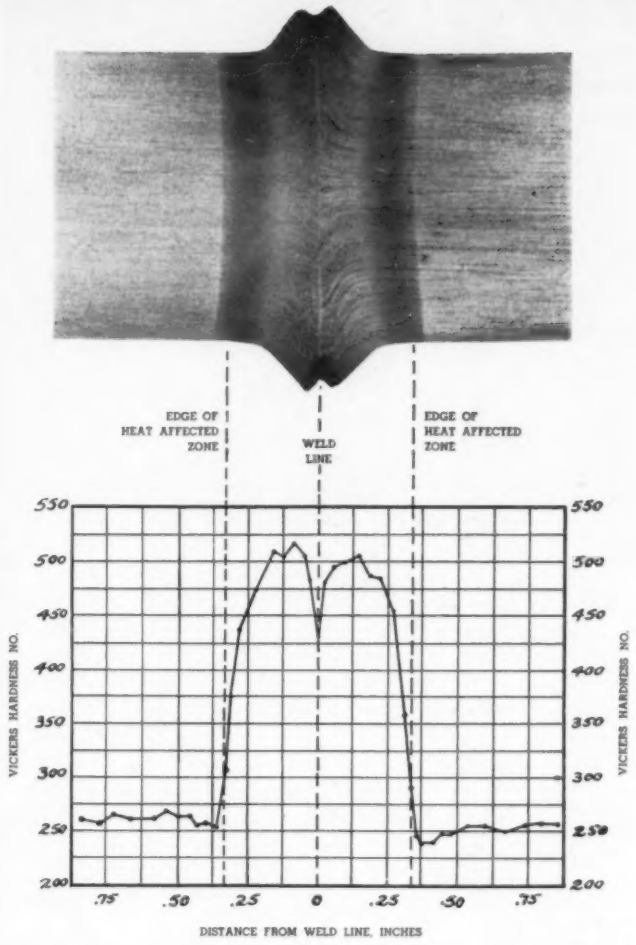


Figure 3 — Photomacrograph and Vickers hardness plot across a flash weld in 1 in. diameter chromium-nickel-molybdenum steel as welded. Specimen etched with 4 per cent nital. Hardness values plotted across the center of section. ↑

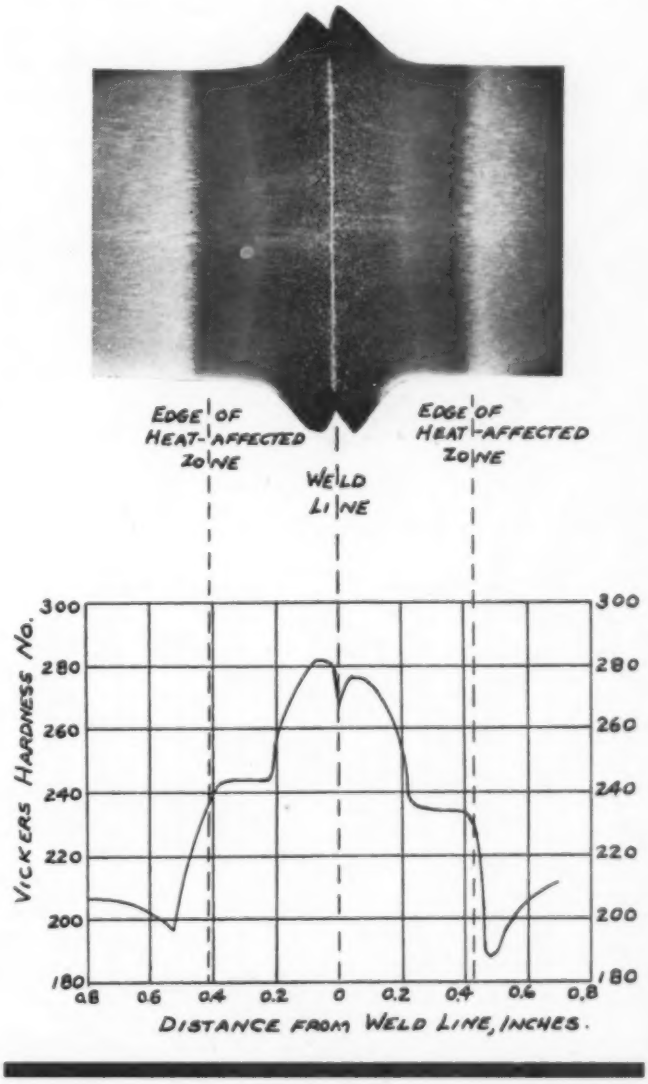
Figure 4 — Photomacrograph and Vickers hardness plot across a flash weld in 1 in. diameter SAE 2315 steel. Specimen etched with 4 per cent nital. Hardness values plotted across the center of section. →

formity of hardness and properties, it is desirable to heat treat after welding. In Figure 5 is shown a photomacrograph and hardness plot of a weld in the aforementioned Cr-Ni-Mo steel after an oil quench from 1550 F and a temper at 800 F. Note the uniformity of the microstructure and hardness plot. Diffusion of carbon has obliterated the slight dip in hardness at the weld line. As a matter of fact, the only thing that distinguishes this weld from a piece of heat treated parent material is the fiber direction in the upset portion of the weld, and a slight indication of the weld line.

There are some applications of flash welded alloy steel parts in which the assemblies are used in the as welded state. In general, with the proper welding schedule, parts which are heat treated to a tensile strength of less than 150,000 psi before welding and tested in the as welded condition develop as much strength as the original parent metal. Beyond a certain size stock, however, the longer flashing times would cause a fairly wide softened band at the edge of the heat affected zone, thus lowering the strength in this region. If the welded part, however, is to have a strength of over 150,000 psi, heat treatment after welding is necessary.

Parts which are heat treated after welding will have full heat treated strength, although the ductility may be impaired by the adverse flow of the upset fibers, particularly when the strength of the material is high. This affect is heightened if the steel has many longitudinal inclusions or chemical segregration ("banding"). Breakage in tensile test follows the upset fibers in such cases, and ductility is low, in much the same way as in a transverse bar in steel plate. Figure 6, which is a longitudinal section through a broken tensile bar, shows the appearance of a fiber break.

Since this upset fiber flow has an adverse affect on ductility, it would seem that the upset should be kept small, so that fiber distortion in the upset region would be held at a minimum. If the upset is too small, however, this purpose is defeated, because of the inability of the upset force to eject molten metal and impurities, such as slag and oxide, from the weld. In general, therefore, it is desirable to use the smallest upset dimension and force consistent with good quality welds, particularly if segregation is present. It may be that at some time in the



not too distant future those people interested in the flash welding of alloy steels will insist on definite standards of cleanliness and absence from "banding" in stock for flash welding.

FLEXIBILITY OF FLASH WELDING

The question arises as to what shapes and materials can be flash welded. In answer to the first part of the question, one may say that two pieces with like section at the surfaces to be butted, with sufficient surface to permit adequate die contact, and with sufficient excess material to allow for burn-off and upset, can be welded together by this method. For example, if one wished to flash weld a forging to a tube, the forging having a prolongation of the same diameter as the O. D. of the tube, it would not be good practice to leave the forging prolongation solid. It should be pierced or drilled so that it presents a hollow section of the same geometry as the tube to which it is to be welded. If the forging were left solid, it would be difficult to establish uniform flashing conditions and uniform upset between the two parts, since the solid forging would conduct heat away from the contact surfaces more rapidly than the tubing; moreover, it would be necessary to supply more heat to the solid bar, because of its larger volume.

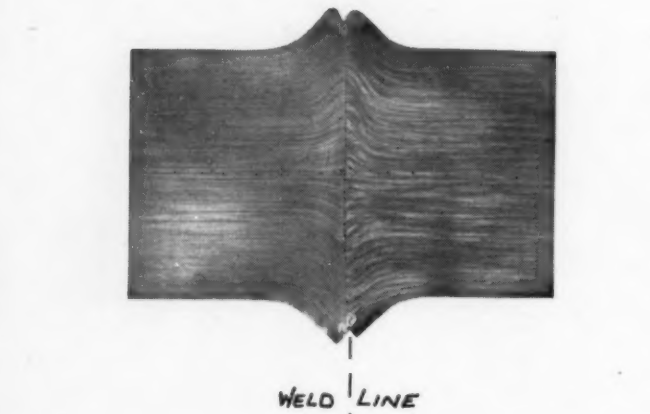
This dictum of like section applies in most cases. There are a few notable exceptions to this rule, which will be considered under the "applications" section. It is usually necessary in these cases to preheat the more massive part of the two before welding in order to compensate partially for the heat unbalance during welding.

The size or the sectional area of the parts to be welded is governed by the size of the welding machine. Sizes up to 6 in. diameter have been welded on large machines.

Any type of steel can be welded by this process, if the proper precautions are taken in every case. For example, in welding tool steels, provision must be made to prevent too rapid a rate of cooling from the welding heat, because of the tendency of these steels to crack in the hardened weld zone. Ways of accomplishing this will be considered further on in the paper.

One of the greatest advantages of the flash welding process is its adaptability to the joining of different types of steels. It is common practice to weld high speed steel or stainless steel to carbon or alloy steel. This not only means a saving in material, but also one can obtain the desired physical properties in both parts of the welded assembly instead of submitting to a compromise, which might be the case if only one steel were used. In welding dissimilar steels one to the other, one must take into account the heat unbalance present due to differences in thermal and electrical conductivity, and in the hot compressive strength. It is difficult to make rules to cover these variables, as they sometimes counteract each other. However, if one finds, in trying one welding schedule, that one of the steels upsets a great deal more than the other, thus tending to bottle in cast metal and impurities, one can provide more heat for the steel of the small upset. This can be done either by preheating this steel prior to welding, or by extending it further from the die, or by both of these methods. Greater initial die extension will provide for more heat and a greater length of plastic material during upset.

Figure 5 — Photomacrograph and Vickers hardness plot across a flash weld in 1 in. diameter Cr-Ni-Mo steel after an oil quench at 1550 F and temper at 800 F. Specimen etched with 4 per cent nital. Hardness values plotted across the center of section.



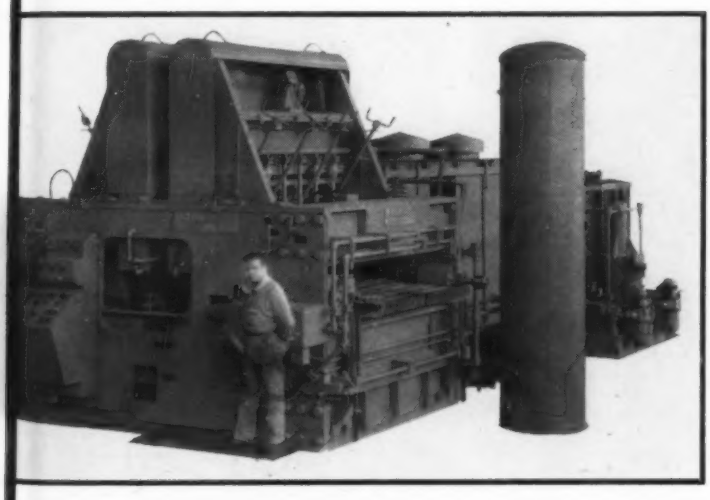
LOW CARBON STEEL APPLICATION

Probably one of the most outstanding of the flash welding applications of low carbon steel is the joining of strip steel coils in steel mills to make multiple coils, either simply to provide for a continuous pickling line or to allow the manufacture of longer coils. Longer coils may be desirable either to minimize scrap losses or merely because of customers' demands for such length. The strip from the hot mill passes through a combination uncoiler and straightener, thence to a shear, which removes the "head-end fish-tails." The head-end of this coil is then flash welded to the tail-end of the preceding coil. After being welded, the coil passes through a trimmer, which removes the upset material of the weld, then proceeds to the looping pit and then to the pickling tanks. The time of welding must be short enough so that the pickling can be continuous. When the multiple coils are to be cold reduced without removing the welds, it is necessary to weld in such a way that the hardness differential between weld and parent metal be kept at

Figure 6 — Photomacrograph shows a broken tensile test bar from a flash welded 1 in. diameter chromium-nickel-molybdenum steel which was heat treated after welding. The break at the edges follows the upset fiber.

▲

Figure 7 — Hydraulic operated 80 in. strip welder, showing general arrangement including controls, pumping unit, accumulator unit, mechanical adjustments, and gas house.



a minimum, so that difficulties will not be encountered in cold reduction. The weld is harder than the parent metal because of the thinness of the sheet and the quenching effect of the dies. In general, with proper welding technique, the hardness differential between weld and parent metal can be kept to 10 to 15 points Rockwell "B." This causes no trouble in cold reduction.

Figure 7 is a photograph of a welding machine capable of handling 80 inch wide strip.

There are many applications involving the welding of low carbon steel rings, such as motor frames, generator housings, truck tire rims, and steering wheels. In manufacturing these rings, a rolled bar or section is formed into a ring and the weld closes the ring. If the ring is of relatively small outside diameter, it is necessary to flatten the curvature on either side of the opening in order to secure adequate die contact and to prevent slipping during welding. Figure 8A shows the appearance of a motor frame prior to welding, with the die contacting surfaces flattened. If the ring is of large outside diameter, it is not necessary to resort to special preparation of this sort.

The welding of a ring poses a problem uncommon to straight welding, since only part of the current can be utilized for welding, the rest shorting around the ring. The smaller the ring becomes, the less the impedance of this parallel circuit (i.e. the ring itself) becomes, and hence more current is robbed from the weld. So there is a distinct size limitation downwards in this class of welding. When the size of the ring is too small, the ring will become red hot during the welding cycle, and difficulty will be encountered in establishing adequate flashing action. A case in point is the welding of chain links; these have to be prepared in two distinct pieces, as shown in Figure 8B, so that there will be no shorting path.

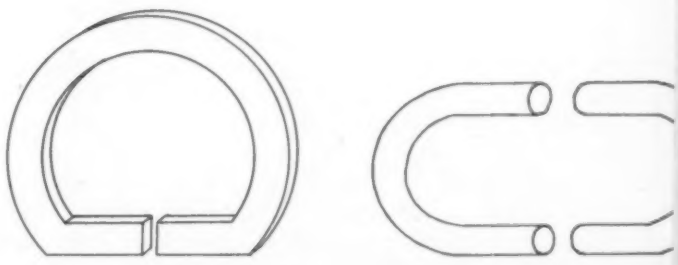
Since rings cannot be adequately backed up, the current carrying halves of the dies are of copper or copper alloy, but those that do not carry current are made of steel with serrated teeth. It is these steel dies which take the brunt of the upset force and prevent slipping of the part.

Figure 9 is a photograph of a large ring welder, with a ring of 18 in. outside diameter in place. The weld has been completed. The serrated steel clamps can be seen inside the ring. The four air cylinders shown are for clamping pressure.

Flash welded assemblies of forging to bars, forgings to tubes, and forgings to forgings are common in low carbon steel. One of these assemblies, containing three welds and composed of three forgings and a tube, forms a valve rocker arm for diesel engines. Foot treadles and levers are common applications.

Before leaving low carbon steel, let us consider one successful application, in the welding of which the principle of like areas was violated. In this case a 1¾ in. diameter bar was welded to the middle of a flat side of a plate approximately 7 in. square and 1½ in. thick. The plate is part of a die set, and the bar which is "T" welded to it is a locator pin. In order to weld this assembly, it was necessary to place a copper bar in place of the

Figure 8 — To the left (A) is shown the appearance of a motor frame prior to welding. To the right (B) is shown how both sides of a chain link have been cut so that there will be no shorting path.



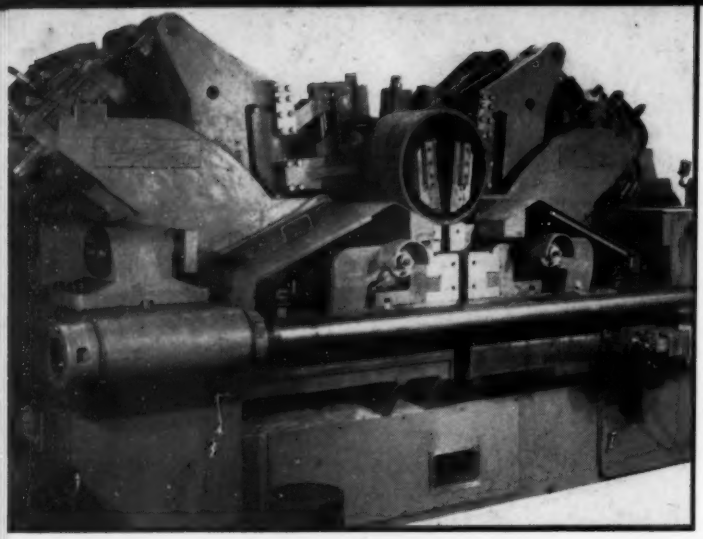


Figure 9 — Photograph of large ring welder, with an 18 in. outside diameter ring in place after completion of the weld.

locator pin in the welder and butt the copper bar several times against the plate with the current on, in order to preheat that portion of the plate to be welded. Preheating having been accomplished, the copper bar was removed quickly, the steel bar inserted, and flashing started. Figure 10 is a photomacrograph of a section through the weld. Observe that most of the upset was taken by the bar. As a matter of fact, practically all the material loss from the plate is the result of burn-off during preheating and flashing. The weld is sound.

ALLOY STEEL APPLICATIONS

The aircraft industry has many interesting applications in the field of flash welding. One of the most notable is in landing gear assemblies. These parts, made up of tubes welded to forgings, are usually either SAE 4130, SAE 4140, or NE 8630 steel, which is heat treated after welding up to 190,000 psi tensile strength. With this high strength requirement, it is necessary that sound welds be obtained. Figure 11 is a photograph of one of these assemblies, showing the outer cylinder assembly and the inner cylinder and fork assembly. The three straight tube welds are qualifying samples, used to set up the proper welding schedule. These parts are usually tested in bending, the bending force being applied at the weld. Preliminary tests carry breakage to completion, not only so that the breaking stress can be calculated, but also so that the fracture can be seen and the soundness of the weld determined. Production parts are often proof tested in bending, at a stress figure below yield point.

For assemblies of this sort, jigs and fixtures are necessary for the proper backing up of the part in flash welding. Figures 12 and 13 show the manner in which such parts are adapted to the flash welding process by proper fixtures. In Figure 12 the assembly is similar to the inner cylinder assembly and in Figure 13 it is similar to the outer cylinder assembly. These fixtures not only locate and back up, but they also preserve the proper length tolerance in the welded part.

Aircraft valves are subjected to corrosion, wear and high heat. They must, therefore, be made of heat resisting stainless steels. On the Wright engine, the exhaust valve is austenitic stainless steel containing, in addition to some tungsten and molybdenum, 14 per cent chromium and 14 per cent nickel. This analysis gives the necessary strength at the high operating temperatures. For tappet wear a tip made of tool steel containing about 1.30 per cent carbon, 12-14 per cent chromium, and some cobalt is flash welded to the stem. After welding and machining, the stem of the valve is nitrided for wear resistance and the tool steel tip is induction hardened to 56 Rockwell "C." The valve seat is coated with Nichrome for wear resistance before welding.

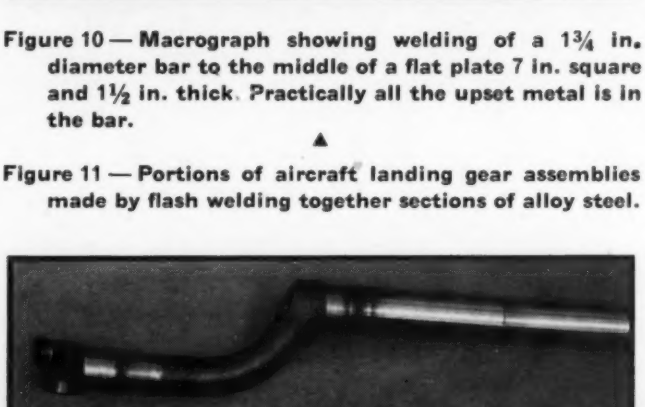
The intake valve in the Wright engine, which does not have to stand the high temperatures of the exhaust, is made of a hardenable stainless steel containing about .50 per cent carbon, 13 per cent chromium, 7 per cent nickel, and 2 per cent silicon. After welding and finishing, the stainless is furnace heated and quenched for hardness, and the tool steel tip is induction hardened.

Figure 14 is a photograph of the intake valve, with the weld clearly marked. The tip is relatively short after final machining, and it can be seen that close

Figure 10 — Macrograph showing welding of a 1¾ in. diameter bar to the middle of a flat plate 7 in. square and 1½ in. thick. Practically all the upset metal is in the bar.

▲

Figure 11 — Portions of aircraft landing gear assemblies made by flash welding together sections of alloy steel.



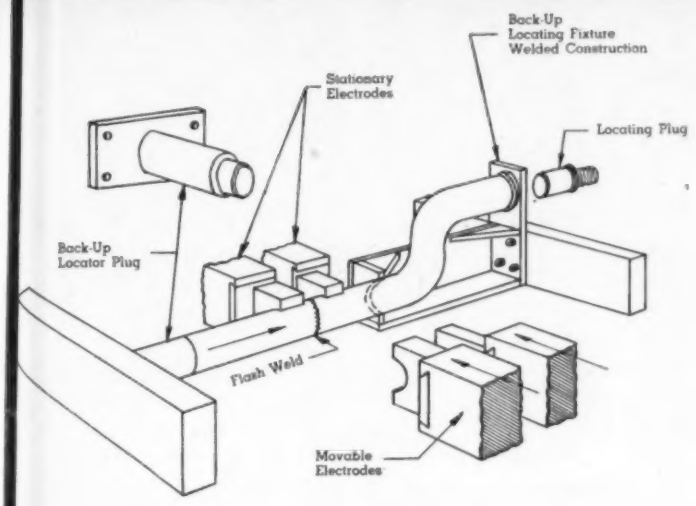


Figure 12 — Sketch showing fixtures for backing up and holding in place for flash welding a section of an aircraft landing gear assembly.

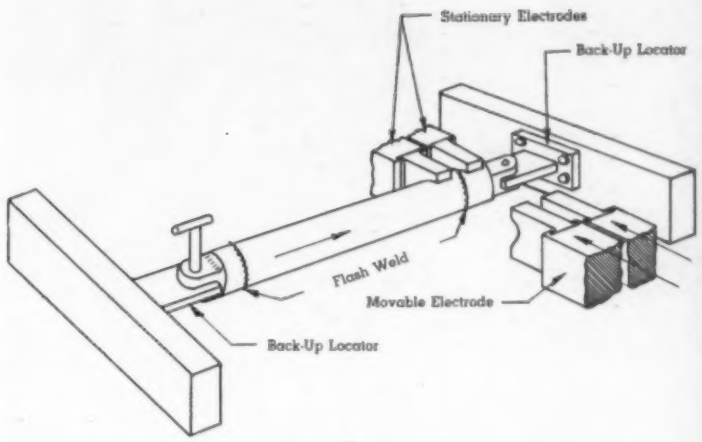


Figure 13 — Another sketch showing fixtures for backing up and holding in place for flash welding a section of an aircraft landing gear assembly.

dimensional tolerances are necessary in welding, so that the weld line will not fall in the retainer groove and yet sufficient tip length can be held.

These materials are subject to localized die burns, particularly the hardenable stainless steel. These burns occur when there is inadequate die contact, so that die surface has to be closely checked. In the case of both types of valves, the tool steel tip is machined in the form of a cone at the butting end, to facilitate the starting of flashing and thereby allowing the process to be fully automatic. All valves are magnaflux tested after welding for weld line defects and die burns. Scrap must be kept at a minimum because of the high cost of the parts.

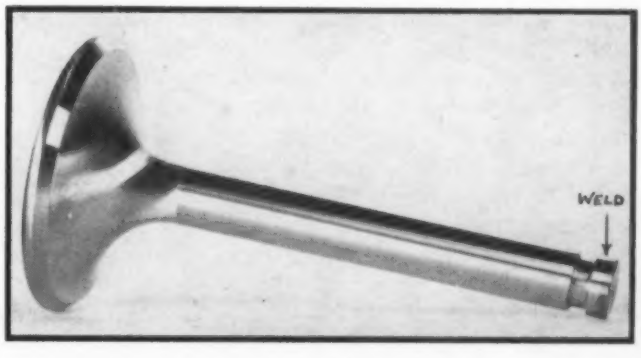
Another example of the welding of dissimilar materials is the airplane supercharger shaft and bucket wheel assembly. Formerly the shaft, of SAE 4140 steel, was bolted to the heat resisting austenitic stainless steel bucket wheel, which made for high machining and assembly costs, not to mention the disadvantages accruing from a bolted assembly. Now the bucket wheel is forged with a short stub shaft on it, to which is flash welded the SAE 4140 shaft. The weld is made at such a dimension from the wheel that little stress occurs here in service. This assembly cannot be fully heat treated after welding, as such practice would destroy the properties acquired in the bucket wheel by forging. Therefore the alloy steel shaft is welded in the fully hardened condition (about 52 Rockwell "C"), and the assembly is merely tempered to the proper hardness for the shaft (about 32 Rockwell "C"). In order that this might be done satisfactorily, it is necessary to flash weld in such a way that there is only a small softened zone in the shaft after welding, and this zone must be at least 28 Rockwell "C" hardness after tempering. This means that the flashing period must be relatively short.

In service the turbine bucket wheel must stand temperatures of 1500 F at its periphery and 1000 F at its hub. The shaft does not reach such high temperatures as this.

Figure 15 shows an etched section through a sample flash weld in these two materials. Note that the stainless steel, because of its high temperature strength, did not upset as much as the SAE 4140. Because of this, there is a tendency to entrap areas of stainless cast metal in the weld line. Two of these areas can be seen in Figure 15. Their presence is apparently not harmful, as long as the weld is sound.

The flash welded Smithway hollow steel propeller blade is a triumph of fabrication, as made by the A. O. Smith Corporation. Figure 16 is a sketch of the seven components of the blade before flash welding; a sketch of the finished blade also is shown. All components are made of a strategic chromium-nickel-molybdenum steel. The shank (1) is made from seamless steel tubing by hot expansion and machining. The tip body (6) is also formed from tubing. Parts 4 and 5 of the center section are of rolled plate, while parts 2, 3 and 7 are forged from bar stock. This fabrication saves many hours of machining and much costly material. All components are joined by flash welding, the longitudinal welds being made first and then the transverse welds. Where the welds occur, the components are made thicker so as to assure full strength. Location and alignment, as well as rigid

Figure 14 — Aircraft engine intake valve made of two kinds of steel, showing weld at tappet end.



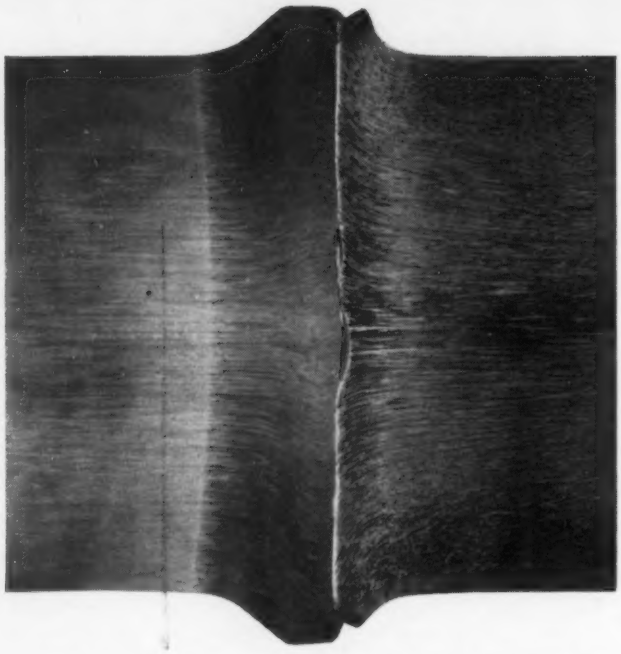


Figure 15 — Macrograph of flash weld etched with 10 per cent oxalic acid, between two 2¼ in. bars, one made of heat resisting stainless steel, (left) and the other of SAE 4140 steel. (right)

welding schedules are necessary in flash welding these parts. Each component is balanced before welding, and the entire assembly balanced after welding. Flash and upset are removed by special belt sanders after each welding operation. After assembly and removal of flash, the blade is normalized and cooled, then reheated and quenched in a water cooled die. Inert gas, under high pressure, passed through the shank opening, serves to push the blade surfaces firmly against the die walls. Hence final forming and quenching are accomplished at one time. Tempering in racks, cleaning, balancing and final polishing complete the job.

TOOL STEEL APPLICATIONS

A saving of high speed tool steel is being effected by the use of flash welding in the manufacture of tools such as drills, taps, and reamers. Only the working part of the tool is of high speed steel; shanks are made of medium carbon or alloy steels, and the two are flash welded together. This process not only adapts itself to new tools, but also to the reclamation of old ones which are too short for use. Since high speed steel is air-hardening, the main problem encountered is the tendency of this steel to crack on cooling from welding. Hence post heating in the welder and slow cooling is resorted to. After the weld is made, the tool is quickly unclamped, the welding dies are placed further apart, and the tool is reclamped. A post heat current is then passed through the welded area, heating it to about 1500 F. When this is done, the tool is removed and buried in lime or mica to ensure slow cooling. The dies are placed further apart when post heating in order to make the heated portion of the piece longer, and thus making for a slower cool. This procedure is adapted mainly to reclaimed tools, as most of the high speed steel portion is not heated to temperatures which would affect its hardness and microstructure. With reclaimed tools, no further treatment than that described is given, since the tool has already been hardened.

In the making of new tools, welding is done before either tool or shank is heat treated. Post heating, then, is not necessary if there is furnace equipment at the welder. The tool is removed from the welder and placed immediately in a furnace running at about 1500 F. It can either be cooled in the furnace or removed and buried in lime. If the tool is a drill, it is welded before twisting. Figure 17 is a photograph of a flash welded drill in the welder just after welding. Note that the shank has been fluted at the welded end to conform to the fluting in the drill, so that like sections are presented to each other. Note also the shape of the dies which contact the fluted drill.

After welding (and twisting in the case of drills) and slow cooling, the tool is annealed at 1600 F in an atmosphere or in cast iron chips to avoid oxidation. It is then machined. The tool end is heat treated according to high speed steel practice, that is, preheated, heated to high temperature, and quenched. It is important that only the tool end be treated this way, since the shank would be coarse-grained and overheated if subjected to the high temperatures necessary for the high speed steel. After the quenching of the tool end, the shank end is immersed in a salt or lead bath at the proper hardening temperature (about 1550 F in the case of SAE 4140).

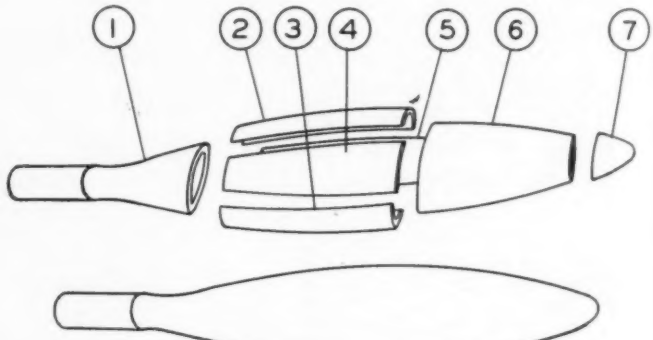


Figure 16 — Sketch above shows the seven components of the Smithway hollow steel propeller blade before flash-welding and sketch below shows finished blade.

▲

Figure 17 — Photograph showing flash welded drill in the welder just after welding.

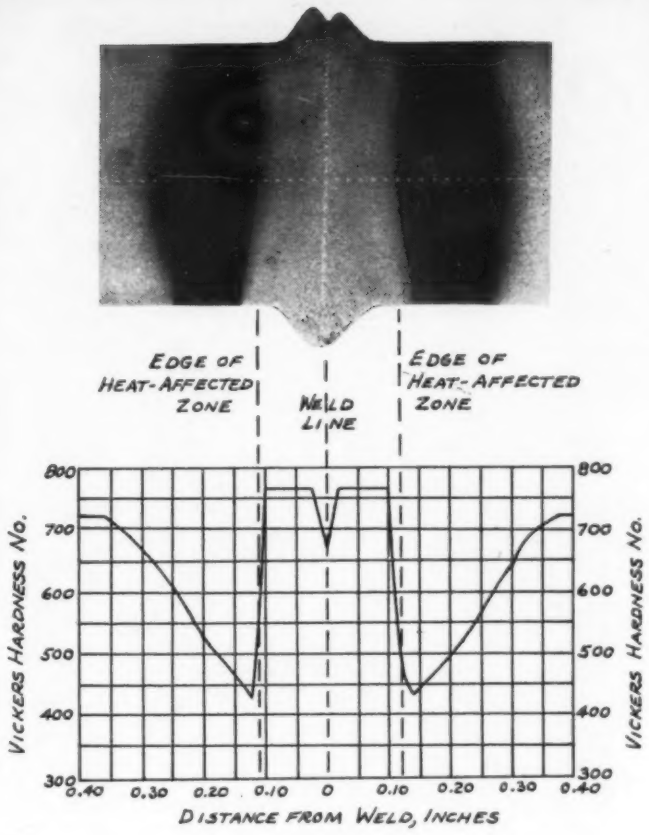


Figure 18 — Photomacrograph and Vickers hardness plot across flashweld in 7/16 in. round SAE 3440 steel. (left)

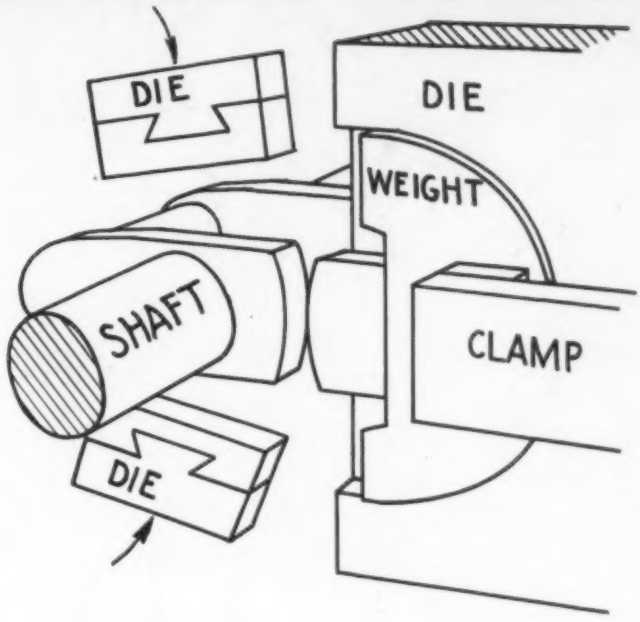


Figure 19 — Sketch showing method of clamping crankshaft and counterweight preparatory to welding. (above)

The shank is then quenched in the proper medium, and the whole part tempered at the proper tempering temperature for the high speed steel. Grinding completes the part.

SAE 3440 steel (.40 per cent carbon, 3 per cent nickel, .75 per cent chromium) is not generally thought of as a tool steel, but it is used for tube drawing mandrels. These mandrels can be rebuilt, when broken or worn, by flash welding without any heat treatment being given after welding, unless it is merely a low temperature draw. The stock is in the hardened condition before welding, and exhibits hardness values after welding as shown on the plot of Figure 18. The weld zone is even harder than the parent metal, while the heat affected zone drops to around 430 Vickers. Apparently this dip in hardness will not impair the wearing quality of the mandrel, which acts as an internal support for the tube while it is being drawn through the die. While this application is not yet in production, it is expected to be soon.

MISCELLANEOUS APPLICATIONS

In the turret ring assembly for turrets of military tanks flash welding plays a major part. The assembly is made of three different rings, the outer ring, which is bolted to the tank body, the inner ring, which forms part of the turret, and, which is connected through gearing to the outer ring, for turret rotation and the retainer ring. All three rings are made of a chromium-molybdenum steel, and are obtained from the mill as rolled section of the proper cross-sectional contour. These long sections are heated and formed into rings, and then the rings are closed by flash welding. Heated once more, they are sized in a sizing ring and flattened in a hydraulic press. The heating after welding serves to normalize the welded area. After being machined, the three rings in the assembly are flame hardened on the ball bearing races. The ring rotates past the flame head, which heats the surface to the proper temperature and immediately quenches it through water jets located directly behind the gas jets. Water with a small percentage of soluble oil is used for quenching, to prevent rusting of the ring and equipment. Flame hardening constitutes the only heat

Figure 20 — Photograph showing a finished crankshaft with sixteen flash-welded counterweights.

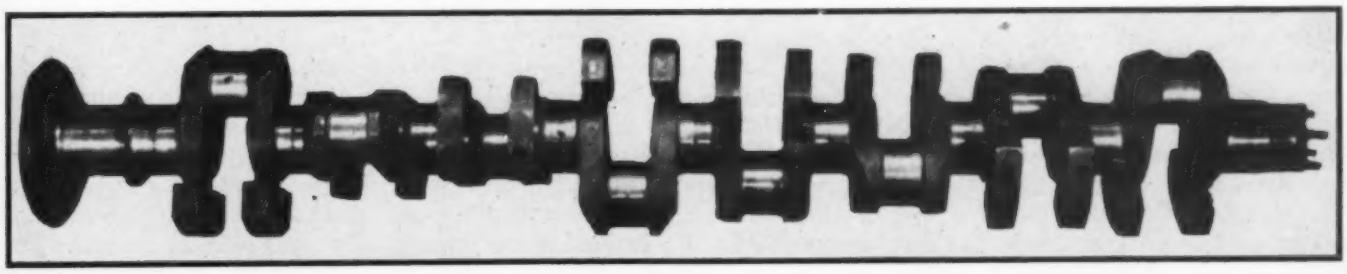


Figure 21 — Closeup of weld between shaft and counterweight after flash and upset has been removed.

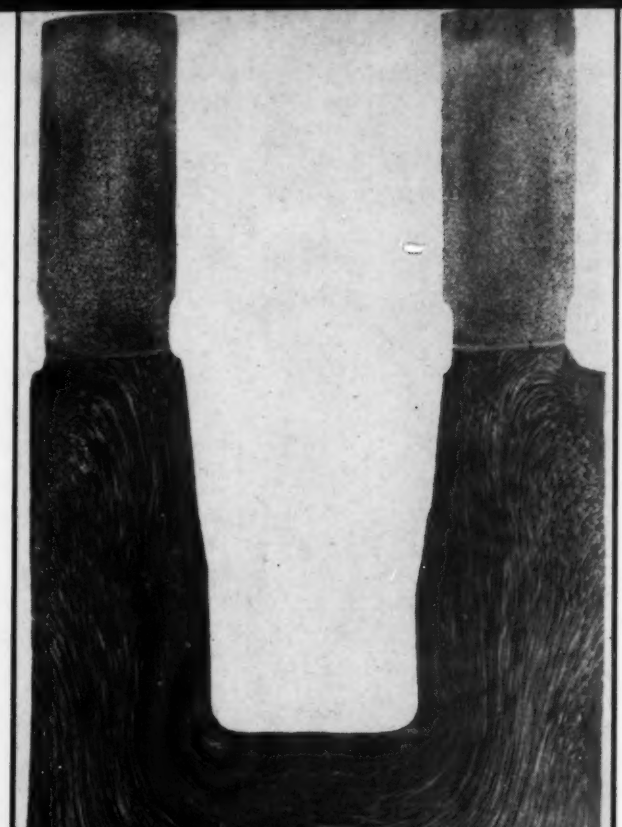
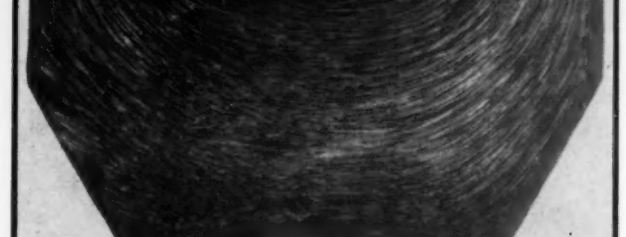


Figure 22 — Macrophotograph of transverse section through counterweight and crankshaft showing difference in structure between counterweight and shaft.

Figure 23 — Photograph of combination jig and die which holds a tractor shifter fork in place for flash welding. A completed fork is shown on the left.



treatment these rings receive. Final assembly of the three integral rings follows flame hardening.

If these rings were not fabricated in this way, they would have to be forged and machined to the proper cross-section, resulting in a waste of both labor and material.

In order that high bearing pressures may be eliminated, crankshafts usually have to be counterweighted opposite the throws. At one time these counterweights were made integral with the shaft, which posed a difficult forging problem. Now counterweights are flash welded to lugs on the shaft. As the centrifugal forces are low, these counterweights are forged from SAE 1020 steel, although the shaft itself can be anything from SAE 1040 to SAE 4340 (chromium-nickel-molybdenum) steel. The shaft is forged, twisted, heat treated, straightened, and grit blasted before flash welding. After flash welding the assembly is retempered, not only to soften the weld but also to relieve straightening stresses, at a temperature about 50 degrees Fahrenheit below the original tempering temperature.

In flash welding, the shaft is mounted in centers at right angles to the welder, and is positioned in the welder by hand wheels. Electrodes on the stationary side of the welder contact the shaft by moving through an arc, as shown in the sketch of Figure 19. The counterweight is clamped into a recess in the electrode on the movable platen, also as seen in Figure 19. Manual preheating is usually necessary to start the flashing action, particularly on the larger sizes, but the remainder of the cycle is automatic. Surfaces to be welded are slightly convex; this also helps in starting the flashing action. Areas up to about 9 square inches are normally welded at Park Drop Forge Company, although a 12½ square inch section was successfully welded once. Figure 20 is a photograph of a finished crankshaft with sixteen flash welded counterweights on it. In Figure 21 is seen a close

up of a weld between shaft and counterweight with flash and upset removed. This photograph also shows the appearance of a forged lug on the shaft before it is welded to the counterweight. Figure 22 reveals the macrostructure of a transverse section through two welds. The difference in structure between counterweight and shaft, the weld line, and the forging fiber in the shaft can be seen..

A relatively recent development in flash welding is the joining of railroad rail sections. While rails are not made of alloy steel, they are high in carbon content (.70 per cent) and so have to be handled carefully to prevent cracking on cooling from the welding heat. As opposed to other modes of welding rails, the flash welding method is faster, gives higher quality welds, and is reproducible because of automatic schedules. To do the job properly, however, much equipment is needed, usually a train composed of a locomotive, a generator car, a rail rack car, a welder car, and flat cars for stress relieving, inspection and grinding. Electrodes in the welding machine are contoured to the rail shape. Welding is fully automatic, with an initial low flashing rate, which also serves as a preheat, followed by a higher flashing rate and the upset. After welding the upset material under the rail base is removed by a shear attached to the welder platen. The welded rail is then removed from the welder by means of a winch and allowed to cool for a predetermined length of time, after which it is moved into a furnace in another car for stress relieving at 1250 F. Cooling from the stress relieving temperature to 600 F is slowed by covering the weld with an asbestos hood. Special grinding machines remove the remainder of the upset material and give the proper rail contour to the welded area.

Let us finish this dissertation by considering one more "T" weld application. This is the shifter rail-fork assembly whose function is to shift the tractor gears on International Harvester Company tractors. Figure 23 is a photograph of the combination jig and die which holds the shifter fork in position for welding, with a fork in place. A cam clamps the side of the fork and a toggle clamp contacts its sloping surface. In the photograph the latter has not been clamped. A block which fits into the fork spread acts as a back-up. The photograph also shows a finished welded assembly. The shifter rail is held in a recessed die and clamped for welding.

Both rail and fork are usually made of medium carbon steel, the former a cold drawn plate and the latter a heat treated forging. The rail is preheated to 400 F before welding, both to allow easier starting of the flashing action and to preclude brittleness caused by fast cooling from the welding heat. After welding is completed, the welded area is softened by local gas heating to about 1150 F, and the part is straightened. It is essential that the wearing surfaces of the fork be at right angles to the rail axis. The wearing surface of the rail, at the notches, is flame hardened file hard, and the wearing surfaces of the fork are induction hardened to 50-60 Rockwell "C" hardness. Sound welds are secured, in spite of the difference in the sectional areas being welded. As in the other "T" weld mentioned, most of the upset is taken by the fork, and the weld line is curved into the rail slightly.

There are many other flash welding applications not mentioned here, but it is to be hoped that a reasonable cross-section of the art has been revealed, and that this paper will serve in a modest way to further interest in flash welding and its applications.

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DISCUSSION

PRESENTED BY

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J. S. HORVATH, Superintendent, Cold Strip Mill, Great Lakes Steel Corporation, Ecorse Detroit, Michigan

J. C. BARRETT, Metallurgist, The Taylor-Winfield Corporation, Warren, Ohio

L. R. MILBURN, Electrical Engineer, Great Lakes Steel Corporation, Ecorse, Detroit, Michigan

H. E. PHELPS, Superintendent, Electric Furnace Department, Rotary Electric Steel Company, Detroit, Michigan

J. G. HOBA, Engineering Division, Kelsey Wheel Company, Limited, Windsor, Canada

A. W. MOHRMAN, Electrical Foreman, Great Lakes Steel Corporation, Ecorse, Detroit, Michigan

T. C. Mayberry: In the flash welding of strip steel from 40 to 90 inches wide, what would be the minimum gauge you could butt-weld successfully without one piece slipping over the other?

William Lueck: Seven thirty-seconds.

J. S. Horvath: Has butt-welding been successful on sheet-strip of .25-.30 carbon, 40 to 90 inches wide?

J. C. Barrett: I do not know why it should not be as far as the mechanics of welding are concerned. If the weld broke, it would be due to brittleness. Some method of annealing after welding would be desirable.

L. R. Milburn: I think on the present welders, you will find that the strip burns off too fast, and when it comes to pushing up, you have no metal there to push up. We have burned off at 14 to 16 volts.

J. C. Barrett: The answer is to use dual voltage. In other words, start at a high voltage and then go to as low a voltage as you possibly can and maintain flashing. You get a more violent flashing action with higher carbon. In addition you may run into difficulty in trying to make the two butting faces equal across when you go to upset.

L. R. Milburn: Then you run into difficulty with a transformer.

J. C. Barrett: No, you can put a switch in the circuit, so that when you reach a certain point on the flashing cam it will throw the switch over to a low voltage. You set your tap for the lower voltage, but you do not let that particular voltage come on until you want it to, or you can change the heat by phase control. I do not know which is better but am partial to the tap change.

H. E. Phelps: In the welding of carbon shanks on high speed twist drills, did you ever have any difficulty in getting scale in the weld, so that when the twisting operation is performed, the weld fails?

J. C. Barrett: No. Of course, you have to watch your heat balance. Since the high speed steel has higher electrical resistance, it heats more readily than does the carbon steel. If it is made too hot, and the current is kept on too long after upset, it is possible to burn the high speed steel.

H. E. Phelps: The thing I was thinking of was a high carbon shank welded to a high speed drill, and since there was much scale, the weld failed.

J. C. Barrett: The current was probably cut off before the upset. You cannot allow any time in which the butting surfaces are open to the air completely. By carrying the current into upset, oxidation is prevented to a great degree, if, on the other hand, current does not flow for a short space of time between the end of flashing and the beginning of upset, oxide can form on the butting surfaces, and probably will not be ejected during upset.

L. R. Milburn: Do you have trouble with insufficient die wear tension in the clamps, due to die wear, when you run a narrow strip for a while, and then go to a wide strip?

William Lueck: Yes, although we have dies that are quickly interchangeable and we have a hook that goes in and picks the lower die out.

T. C. Mayberry: What is the average life of these dies for different strip steels?

William Lueck: That is a question of how you use them. If you change from wide to narrow stock, where the pressure is localized in one place, it lowers the die life. The dies are made heavy to allow for wear, and the dies are made so they are adjustable. They have a wedge underneath to permit their alignment.

T. C. Mayberry: Do they get pitted up, afterward?

William Lueck: Yes.

L. R. Milburn: Is it not true that you have no trouble welding as long as your steel is the same gauge all the time? In other words, you can then make your setup just so. But when you come to a steel mill which runs all classes of steel and all widths, the machine must be maintained in a precise manner all the time.

William Lueck: That is one reason there are adjustments in the dies.

L. R. Milburn: But you cannot compensate for the wear in the center, except by taking out the dies and grinding them down.

William Lueck: That is correct.

T. C. Mayberry: Do you have any method to clean dies?

William Lueck: Yes, if you mean to take the oxide off the face of the dies. There is a space bar that cleans the die face.

J. G. Hoba: We recently attempted to flash weld a band of steel 23 in. in diameter, 7 15/16 in. wide and 3/8 in. thick, made from a low alloy class B, grade one, spec. 57-114-1, or NAX-9110 steel. The experiments that we performed were on NAX steel, and were done on a 600 kva, 25 cycle cam-operated flash welder.

We did not have very much success in our experiment, primarily, we think, because there was not sufficient clamping pressure on the metal during the upset period, and it would simply dislodge itself in the welder jaws. Of course we experimented with the different variables in a flash welder, such as amount of current, time element, point of cut-off, etc., but in all cases, the metal would simply flash violently and blow out large pieces.

We have been able to find out some interesting facts in comparing welding of steel in our Detroit plant, at 60 cycle power, and in our Windsor plant at 25 cycle power. It seems that our 25 cycle power on an identical machine rating is considerably "hotter." For similar jobs we never do require as high a machine rating in our Canadian plant as they do at the Detroit plant.

T. C. Mayberry: Have you tried a-c welding of strip for alloys with carbon above 30 points?

J. C. Barrett: We weld low carbon thin stock without any difficulty, but I do not know about strip in the higher carbon or higher alloy steels.

A. W. Mohrman: You would have more trouble with high carbon due to brittleness. It would be all right if you could provide for some way of slow cooling or annealing the strip afterward.

T. C. Mayberry: In other words, if we are to successfully weld high tensile steel, it must be done before the start of the continuous pickle, since it cannot be done in a continuous pickle line if it is necessary to anneal afterwards.

J. C. Barrett: I should think you would have some difficulty along that line. Even if you managed to weld successfully you would have trouble in cold reduction afterwards, because you would have an appreciable difference in hardness from the weld metal to the parent metal. Even with a low carbon steel, when you add a little alloy, you may be surprised at what happens.

J. S. Horvath: Would it be possible to weld high carbon strip and anneal quickly?

J. C. Barrett: I do not see why not. You would have a soft zone at one point outside the weld, due to heating in the high tempering range.

J. S. Horvath: I noticed the welds illustrated in the paper have quite an upset. The trouble we are having welding high carbon strip is that there is no upset. The steel is all gone, and you have only prime surface. I would judge that if we did want to anneal, we still would not have enough stock to hold, as our welds tend to break as soon as it is bent.

J. C. Barrett: The answer to that, I believe, would be to increase your upset distance.

William Lueck: You should also change to a low voltage. Possibly there is not enough clamping pressure, for with too high a secondary voltage, the metal is all flashed away, leaving insufficient metal to upset.

J. S. Horvath: The clamping pressure has been great enough, but the material burns away faster than we are able to push up on it.

J. C. Barrett: You need high enough voltage to start the flashing action, and then you need low voltage to continue the flashing action without blowing out large particles.

L. R. Milburn: When you are making a weld, you turn the current off before you finish the push-up. Would it do any good to turn the current back on again before unclamping?

J. C. Barrett: Let us assume that you have allowed the weld to cool to a low temperature so that it has transformed. Then if you could control the heat in such a way as to get uniform tempering, it would be helpful.

LARSEN AND SIDDALL

Discussion

(*Continued from page 96*)

half or two-thirds of the bath with its maximum luminosity and radiation power at about the first door, and I think that is in line with some of the results Mr. Fisher has given.

In this mixing of coke oven and blast furnace gas, if you actually could preheat the gas mixture in the regenerator and get all the reaction between the two gases to take place and at the same time somehow carry enough of suspended carbon from excess hydrocarbon to give luminosity in the chamber, it would then seem to be a fairly ideal fuel, because the hydrogen content is down so that that fuel would be a heavy fuel and I think its flame would then tend to lie down along the bath.

The main problem is probably luminosity. You could perhaps not run the coke oven gas percentage up high enough and carry enough carbon to get maximum luminosity.

It may be we will have to go to injection of finely divided oil or carbon as Mr. Fisher points out.

There is a metallurgical aspect to fuel burning of course, but I think this can be kept secondary to the main problems of regenerator efficiency and radiating rate. If we can generate an intense flame without burning out the incoming end of the furnace too much, and distribute much of the heat along the first ⅔ of the bath, it seems to me that we can visualize pushing fuel efficiencies up higher and higher, and perhaps if necessary we will have to build furnaces with basic roofs or ends in order to take advantage of the maximum efficiency. In other words, you should not give up on maximum fuel efficiency just because the present open hearths are not able to stand the gaff.

The essential point about mixed gas is that, if we could give its flame a high luminosity to transfer heat about as well as oil or tar, its greater capacity for returning regenerated heat might give it equality or even superiority in a modern, efficient furnace system.

IMO pump circulating governor oil and lubricating oil for large turbine.

The IMO PUMP requires less space than most other pumps because of the high capacity attainable by its efficient, compact design and high speed operation. If desired, it can be directly connected to, and mounted upon, turbines, motors, engines, or other equipment. In special designs, dimensions and proportions can be varied to meet space limitations. I-128

For further information write for Catalog I-128-1.

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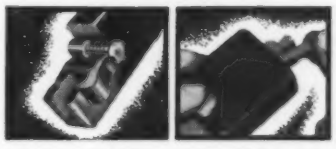

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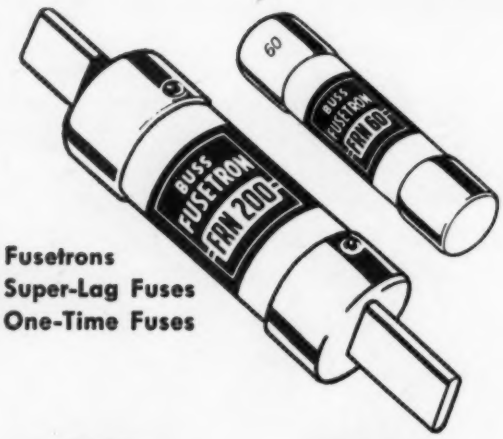

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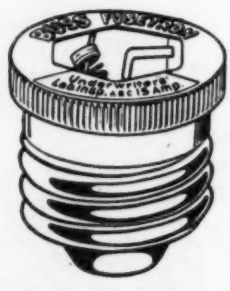

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CARNEGIE-ILLINOIS ANNOUNCES FURTHER IMPROVEMENTS AT GARY AND IRVIN WORKS

▲ A program for further improvement of facilities for the manufacture of cold reduced sheets and tin plate at the Gary Sheet and Tin Mills of Carnegie-Illinois Steel Corporation, Gary, Indiana, has been announced by J. L. Perry, president of this United States Steel subsidiary. The new program supplements a previous project announced last June. When completed these improvements will increase the mill's annual capacity for cold rolled products by 232,600 tons.

These improvements will enable Carnegie-Illinois to give better service to mid-western manufacturers who use cold reduced steel sheets for making automobile bodies, refrigerators, household appliances, enamel wear and similar sheet steel products, as well as users of tin plate and cans.

The new program includes increasing the capacity of the plant's 80-in. hot strip mill. In this mill, which was completed in 1936, slabs of steel, which average 5½ in. thick, 40 in. wide and 105 in. long, pass through a series of rolls, known as roughing and finishing stands, where they are reduced in thickness until they emerge ready for coiling as strip 1/16 of an in. thick and about 1400 ft long. During the war years this 80-in. mill was converted, in record time, to also produce heavy steel plate for ships.

As part of the improvement program a new 54 in., four-stand cold reduction mill will be installed and improvements made on the present 84-in., three-stand cold reduction mill. In this type of mill, the coiled strip from the hot strip mill is further reduced in thickness and receives the smooth surface required in finished steel products.

In connection with these improvements, the 18 year old, 42-in. hot strip mill and 10 thirty-five year old hand sheet mills will be dismantled.

Another modernization program has been announced by the corporation for the Vandergrift Plant of Irvin Works, where facilities will be installed for the production of steel strip in coils.

To complete this program, a modern single-stand reversing cold reduction mill will be transferred from Irvin Works to the Vandergrift plant, and necessary annealing equipment and other finishing facilities will be installed. When completed, the plant will be prepared to meet the newly developed consumer demand for electrical steel strip, which is preferred by manufacturers of electrical equipment.

The Vandergrift plant was the first steel plant in America to produce silicon sheets although they were manufactured previously in England. In the past practically all silicon steel was delivered to the user in the form

WORLD'S LARGEST MORTAR BUILT BY MESTA

With the end of warfare, the army revealed the closely guarded secret of the 36 in. mortar, built by Mesta Machine Company of Pittsburgh. The original plan was for Mesta to make only the barrel, a forging 38 ft long and weighing 90 tons including the mount. But, according to Lt. Col. John W. Kight of the Pittsburgh ordnance district, Lorenz Iversen, Mesta's president, was later given a free hand to design the carriage and recoil mechanism as well. The giant mortar, probably the largest ever built, was planned, designed and produced ready for action in only four months.

The gun and the emplacement unit, which weighs another ninety-one tons, were transported to the Aberdeen proving grounds from Pittsburgh for testing. Over Pennsylvania's superhighway the huge gun was moved at a speed up to seventy-five miles an hour.

The mortar throws a two-ton shell six miles. In spite of the fact that the recoil charge is eight times that of a 16 in. naval gun, it is absorbed in the space of 25 in. in 45/1000 of a second.

of hot rolled sheets. The new program results from research and studies which U. S. Steel metallurgists and engineers have carried on for several years to devise means of producing this electrical steel in coiled form, as either hot rolled or cold reduced strip.

It is estimated that the entire reconversion program at this plant will be completed late in 1946.

NEW BRAKE CONTROL UNIT PROVIDES CUSHIONED STOP UPON POWER FAILURE

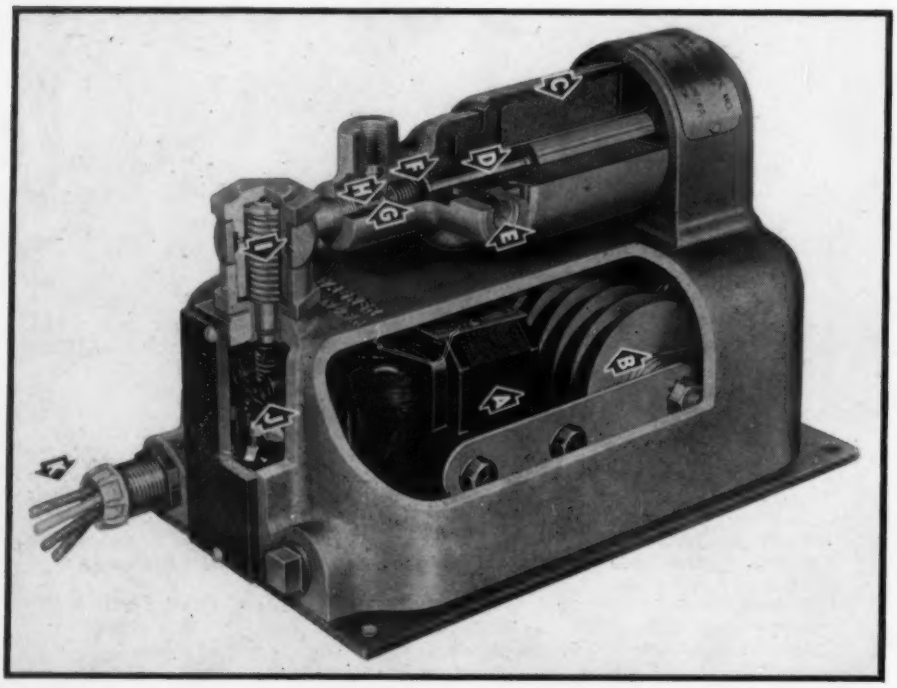
▲ A new brake control unit recently developed for the Wagner type HM crane-bridge brake provides automatic "cushioned" emergency stops when power fails or crane runs beyond safe limits on the runway. This brake control unit permits free use of the foot controlled hydraulic brake for service stops while at the same time it holds the parking-brake setting-spring compressed and ready to apply the brake in an emergency, such as the over-running of a limit switch, power failure, or in the event the operator wishes to park the crane. In either event the "cushioned-stop" valve of the control unit applies the brake at a predetermined rate to bring the bridge and its load to a quick, but smooth, stop without undue swinging of the suspended load.

The unit shown in the cut-away photograph is for use with alternating current and has a transformer (A) and a selenium rectifier cell (B) that converts the line current to 12-volt direct current for operating the "cushioned-stop" valve. In the direct current unit, resistors are used in place of the transformer and rectifier.

While the crane is in operation electromagnet C is energized, holding plunger D against escape port in sealing cup F. In this position whenever the operator uses the brake for service stops fluid enters port E and goes directly to the brake actuating-cylinder from outlet port (hidden in this photograph) opposite of port E. When line circuit K is opened, as by a limit switch or power failure, magnet C is de-energized, releasing plunger D and permitting the escape of fluid from hydraulic-releasing cylinder mounted on the brake. This fluid must pass metering disc G which meters the escape of fluid so as to allow the brake to set by spring action at a predetermined rate.

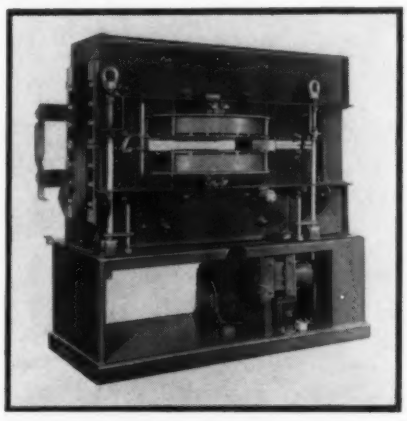
To release the parking brake the operator makes a full application of the foot pedal. Fluid entering port E passes readily through sealing cup F, since magnet is now de-energized, and out the lower port to the hydraulic-releasing cylinder to compress the brake-setting spring. Fluid is also forced through tube H and acts on plunger I to close switch J. With the closing of switch J magnet C is energized thereby trapping hydraulic fluid in the releasing-cylinder and holding the brake-setting spring compressed.

With this control unit installed in the system, the operator has a hydraulic brake for service stops, a spring-set brake for parking, and an automatically applied "cushioned-stop" brake for emergencies — all in one brake.



BETATRON OFFERS TOOL FOR X-RAY PICTURES

▲ The first industrial application of one of the newest electronic devices — the 20,000,000-volt betatron which has been in use for more than a year in a Government arsenal — was disclosed recently by the University of Illinois and Allis-Chalmers Manufacturing Company, who cooperated in making the betatron available for industry.



This betatron, located at University of Illinois, is able to take pictures through 15 in. of steel.

Generating X-rays more powerful than any ever before used in commercial radiography, the betatron enables engineers to take pictures through 15 inches of solid steel. Through use of the machine, minute hidden defects may be detected in high castings and forgings.

Despite the high voltage of the X-rays, the betatron can be handled as easily as the low voltage equipment familiar to anyone who has had X-rays taken on a visit to his doctor or dentist. However, it remained a laboratory tool until the war brought it into industry. Funds for the research carried on at the university and Allis-Chalmers were provided by a contract with the Office of Scientific Research and Development.

The machines are operated by push-button and have automatic controls for timing photographic exposures so only ordinary X-ray technician skill is needed to take successful radiographs. For instance, heavy battleship parts which previously could be given only a surface inspection can be penetrated and the inside revealed as though it were completely open to an inspector's eye.

So far, only a few of the many applications expected for the 20,000,000-volt betatron have been explored. However, larger machines have been projected, at least for laboratory work, and indications are that they will play an important part in nuclear physics (cosmic ray and atomic research).

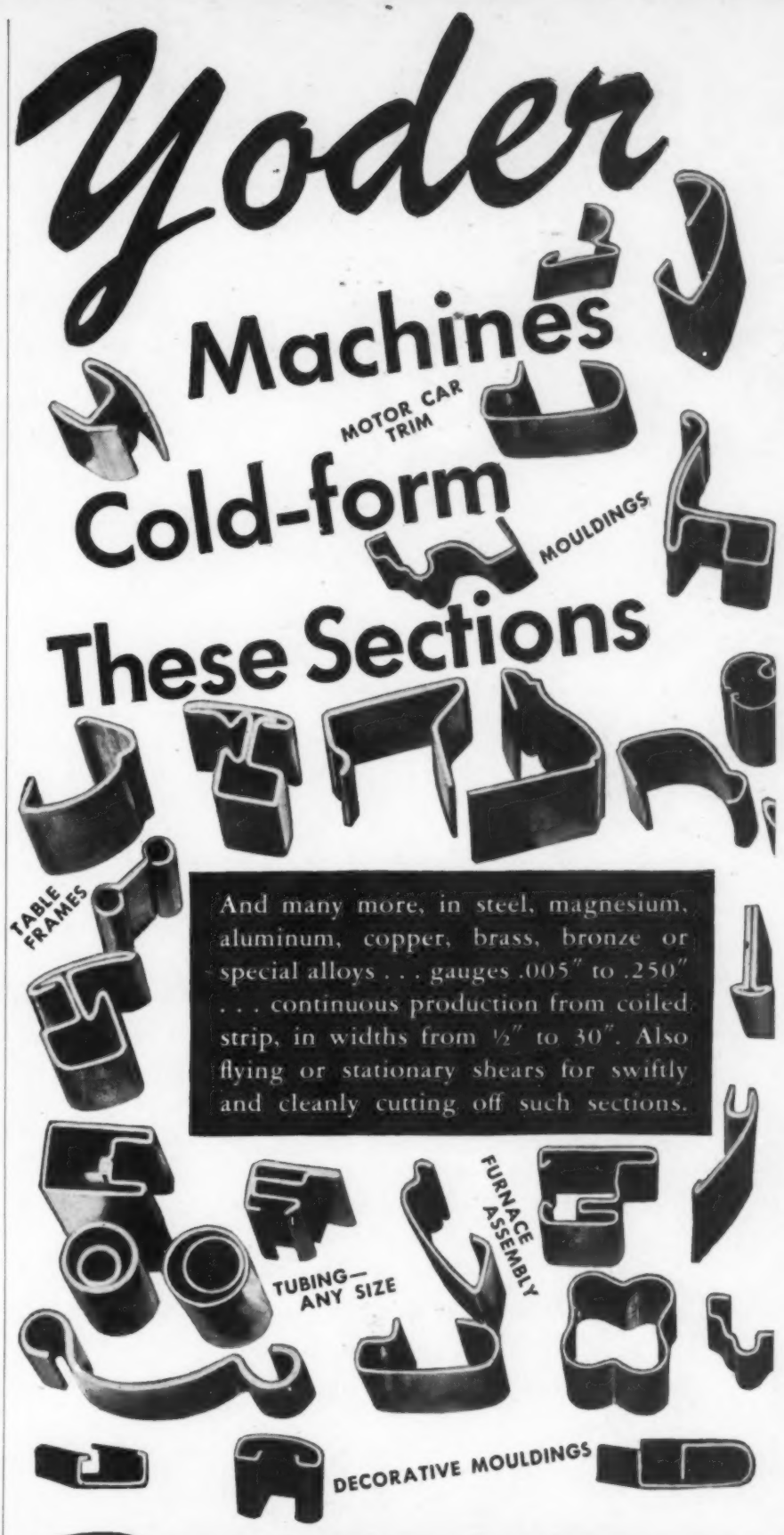
ACID OPEN HEARTH STEEL OUTPUT 2.17% OF TOTAL

▲ The bi-monthly meeting of the Acid Open Hearth Research Association, Inc. was held on Thursday, November 8, at the University of Pittsburgh. During the business session, F. C. T. Daniels, Secretary, announced the results of a survey of production statistics for the entire acid open hearth industry during 1944. The compilation indicated that the value quoted by the American Iron and Steel Institute (1,196,000 net tons) was actually only 60 per cent of the total acid open hearth production. The actual 1944 figures were as follows (one small non-member plant not reporting):

	Net tons	Per Cent
Ingots	946,034	49.07
Castings	981,696	50.93
Total	1,927,730	

A further breakdown indicated that this total represented 2.17 per cent of the total U. S. steel production during 1944, and that 69 per cent of all acid open hearth steel was produced by members of the association.

Completion and distribution of the first research bulletin, "Acid Open Hearth Slag Fluidity and Its Significance" were also announced. This bulletin is available to non-members at $1.00 per copy and may be obtained from the Secretary, P. O. Box 1873, Pittsburgh, Pennsylvania.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NEW MUFFLE FURNACE APPLICABLE TO CARBURIZATION OR GENERAL TREATING

▲ For increased flexibility in handling different batch type heat treating operations, a new atmosphere muffle furnace is now offered by Surface Combustion Corporation, Toledo 1, Ohio. Due to a new feature of design the furnace can produce the proper atmosphere for gas carburizing, yet also is applicable for general heat treating. (Figure 1). In addition all the features of "Surface" Char-Mo heat treating furnaces, including atmosphere and uniform temperature distribution are provided.

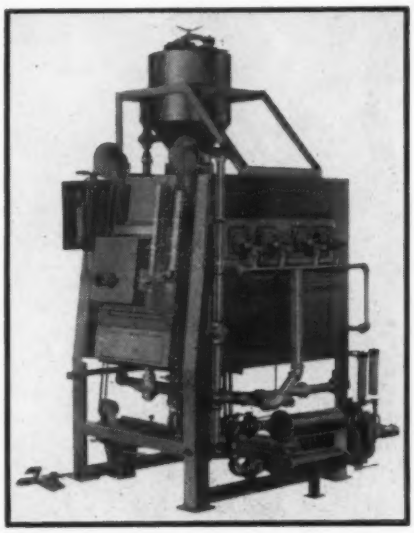


Figure 1 — Surface Combustion standard Char-Mo carburizing furnace.

After producing the basic atmosphere, the furnace utilizes a new gas enriching and recirculating system for gas carburizing (Figure 2). Instead of circulating all the gas in the muffle through the enriching system, thus tending to cool the entire amount, only about 10 per cent is removed from the muffle at any time. This gas is continuously withdrawn near the door, and is first filtered to remove any free carbon which may have dissociated from the CO in the atmosphere. After filtering the atmosphere gas, the enriching gas (raw material gas or propane) is added through a metering orifice. The gas then passes to the recirculating pump, which is of the positive displacement (vane) type. The gas under pressure is discharged at high velocity into a venturi within the muffle, inspirating into the venturi a large volume of muffle gases. These are mixed in the venturi and are discharged to recirculate throughout the muffle.

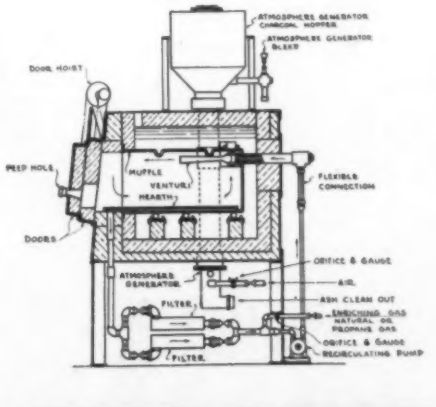
Indicative of the flexibility of the unit, conversion from a carburizing to a heat-treating atmosphere and vice versa can quickly be made without shutting down. Nor is it necessary to shut down for filter cleaning, since a twin filter unit is supplied. In operating tests carried out over some months it has for instance been found convenient to use the unit for hardening work during the day, then operate it as a carburizer during the night shift.

For rapid heating the furnace is equipped with over-muffle and under-muffle burners. The time to temperature ranges from 2½ to 3 hr. The heating rate is given below for heating a cold charge to 1700 F with the furnace initially at this temperature. The rapid rate of carburization obtainable is indicated by the results on SAE 1020 steel, for which the time at temperature of 1700 F to obtain a case depth of 0.020 is 1 hr, and for 0.070 is 7 hr.

The furnace is available in three sizes, for light or medium batch operations.

The furnace utilizes a selective double door to facilitate handling pieces of various sizes with least loss of atmosphere. The inner door has a small opening for the insertion and removal of small pieces, whereas both doors may be opened for large pieces. Both doors are of air-lift type, oper-

Figure 2 — Diagram of prepared atmosphere circulating system for carburizing furnace.



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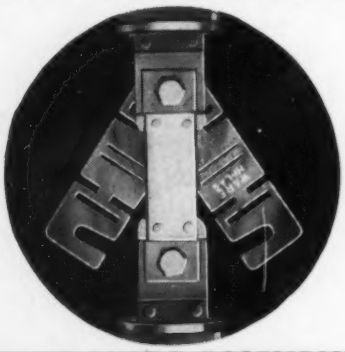

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ated by a tilting treadle with manual selector.

The control panel is mounted at eye level on the furnace shell to the left of the door. Two flow meters are regularly supplied, one for air to the generator, the second giving the flow of carburizing (enriching) gas. The charcoal container is mounted on top of the Char-Mo gas generator which is built into the furnace. The basic atmosphere gas for the furnace is made by reacting carbon (charcoal) with air in a generator built into the furnace so that the gas is formed at furnace temperature. A small portion of the generated gas thus formed is bled from the hopper to eliminate from the charcoal all moisture and volatile products before it is used to generate the atmosphere gas which is introduced into the muffle. Filters are at floor level, easily accessible for cleaning.

INDUCTION HEATERS USED IN FORGING PRODUCTION LINE

▲ Spotted right in the production line, induction heaters of a new design speed the heating of bars or tubes for forging, upsetting or spinning — in seconds instead of hours. To facilitate handling of the work, the Ajax-Northrup heaters are mounted vertically on a compact control cubicle.

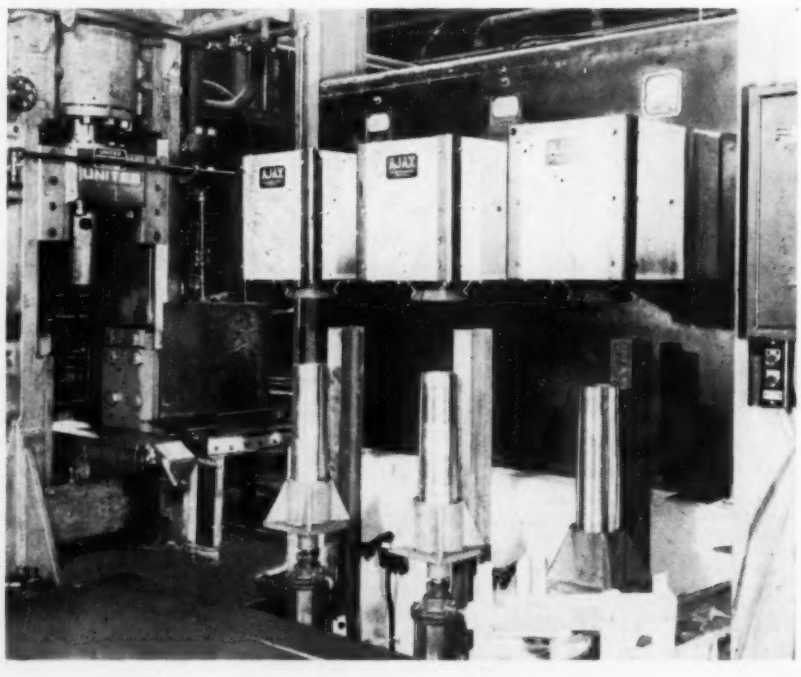
The part to be heated, held in a fast-loading holding cup, is thrust up into the heating coil by a pneumatic ram. Power is applied, and is automatically cut off when the exact temperature is reached. The pneumatic ram then lowers the heated piece, which rolls to the forging machine on conveyors.

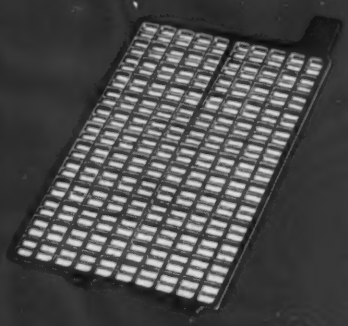
In the installation shown, at United Engineering and Foundry Company, three heaters are mounted on the control cubicle. Two of the heaters work while the third is being unloaded and reloaded. Speed is one piece per minute for each heater, with 250 kw motor generator power source. Controls are simple to operate, and automatically timed to the split second.

Each piece gets exactly the same treatment — top heat at the end, tapering off toward the unworked portion. On the press a few seconds later, the metal flows smoothly to form the correct shape. Practically any differential heating pattern can be achieved by proper coil design. Scale is negligible, resulting in longer die life and less die cleaning.

Simply by changing the heater taps and the time cycle, or by substituting relatively inexpensive heaters of different sizes, the same Ajax-Northrup equipment can quickly be converted to many different heating operations.

In this battery of three induction heaters, two heaters are working while the third is unloaded and loaded.





KATHANODE GRID
Cast to a special design, the Kathanode grid retains its power-conducting capacity for the entire service life of the battery.

GOULD STORAGE BATTERY CORPORATION, Depew, N. Y.

Factories: Atlanta • Boston • Chicago • Dallas • Depew • Leavenworth • Los Angeles • North Bergen • Rock Island • Saint Paul • Salem • Sioux City • Zanesville

ARE YOUR TRUCKS

MAKING THE GRADE?

Gould Kathanode power gives your electric trucks extra flexibility. They will climb ramps to loading platforms even when heavily laden. Hoists can be operated while vehicles are still in motion.

Gould Kathanode batteries meet extra power demands. One reason is the special design of the positive grid. Among other features this has double-wedge-type members. There is ample cross-section for conductivity, yet only a knife-like edge is exposed. Peroxidization cannot reduce battery efficiency prematurely.

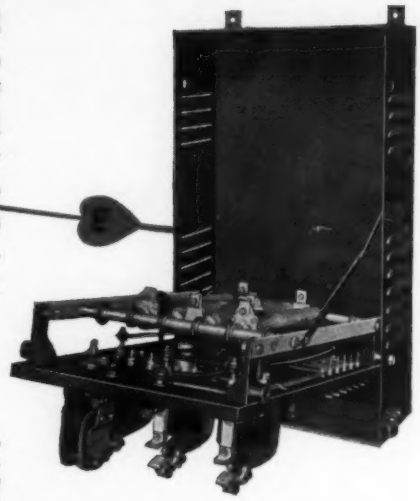
Investigate Gould power for your electric trucks. Write Dept. 412 for Catalog 100 on Gould Kathanode Glassklad Batteries for Industrial Truck and Tractor Service.

GOULD
KATHANODE

BULLETIN 7400 VARITIME CONTACTOR *is the* HEART *of all* CLARK HEAVY DUTY DC AUTOMATIC STARTERS

"3C" BULLETIN 7400 VARITIME CONTACTOR

The heart of these starters is the "3C" Varitime Contactor—which incorporates *within itself* an adjustable time delay—making it ideal for service as an accelerating starter on heavy duty DC motors. Since accelerating relays are unnecessary, wiring is simplified, fewer parts are required, and maintenance reduced—timing element needs no service or repair.



A. Bulletin 5370, Size 5, Type B, Form 3 AL Non-Reversing, Dynamic Braking, Adjustable Speed Starter,—cover removed. This control has Type FL (Field Loss) Relay, for preventing motor run-away if field should burn out or in some way become de-energized.

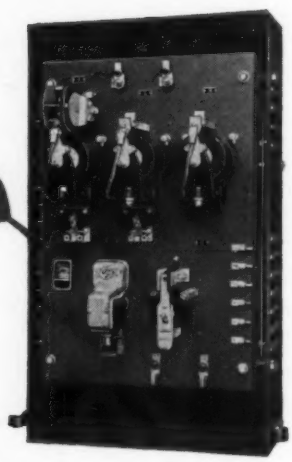
B. Bulletin 5370, Size 2 Type RB, Form 2L Reversing, Dynamic Braking Starter. Bulletin 5370 Starters are suitable for use with Shunt or Compound Wound DC Motors on drives where frequent starting is required as with various machine tools, fans, blowers, pumps, etc.,

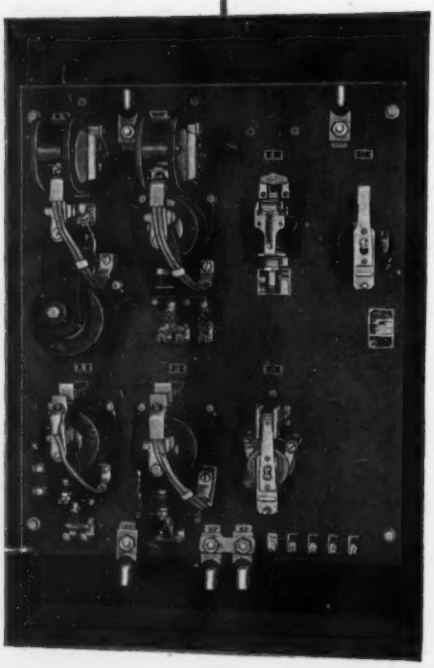
C. Bulletin 5370, Size 2, Type P, Form 2, Non-Reversing Constant Speed Starter. Illustration shows control without enclosing cabinet. NEMA Type 1 enclosing cabinets are standard on Bulletin 5370 Starters, but other types of enclosures are available for specific applications.

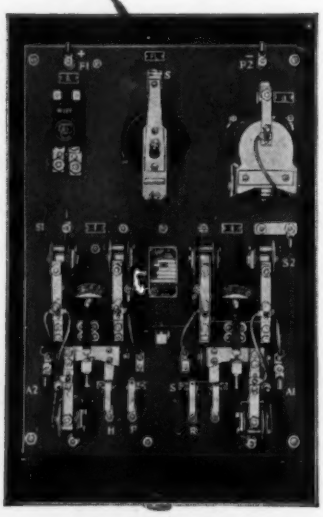
D. Bulletin 5380, Non-Reversing Adjustable Speed Heavy Duty Mill Type Automatic Starter—cover removed. These starters are used in heavy-duty applications and in connection with Shunt or Compound Wound, Constant or Adjustable Speed DC Motors.

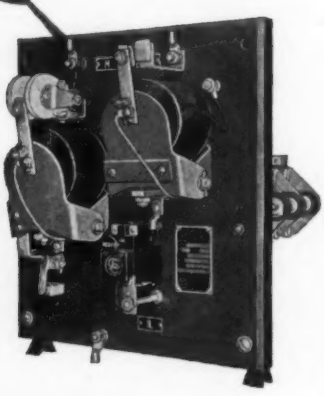
E. Bulletin 5380 Starter same as "D", showing swing-out arrangement on the slate permitting easy access to rear of panel for routine maintenance.

Ask for descriptive Bulletins 5370 and 5380









THE CLARK CONTROLLER CO.

1146 EAST 152nd ST., CLEVELAND 10, OHIO • EVERYTHING UNDER CONTROL

IMMERSION THERMOCOUPLE TAKES MOLTEN STEEL TEMPERATURE IN 45 SECONDS

▲ An immersion thermocouple for molten steel temperature measurement has been announced by The Brown Instrument Company, Industrial Division of Minneapolis-Honeywell Regulator Company. The new thermocouple is referred to in the metallurgical field as a revolutionary advance in steel processing. The temperature of molten steel is measured within 45 seconds, regardless of steel composition and slag, with the Brown ElectroniK "Continuous Balance" Potentiometer and the new immersion thermocouple.

The thermocouple consists of a detachable angle-type immersion head and a long extension handle, as shown in Figure 1. The immersion head has a rugged detachable plug, an inner and outer condulet, a heavy graphite block for passage through the slag layer, a ½-in. diameter fused silica protecting tube, and a 30-in. platinum and platinum-rhodium thermocouple with double bore sillimanite insulation. Although the overall height of the immersion tip is only 16 11/16 in., a 30-in. thermocouple is used with the excess wire coiled on a ceramic spool for use as needed. This length is sufficient for approximately 375 immersions.

Available in 10-ft lengths for electric furnaces up to 15-ft in diameter and 14-ft lengths for larger electric and open hearth furnaces, the extension handle is of heavy durable construction. A secondary tube of 2-in. diameter extra heavy pipe surrounds that part of the handle exposed to intense furnace temperatures. The annular space between the extension handle and secondary tube is insulated with rock wool to prevent possible overheating. On the end of the handle, a second detachable plug is provided for connection to the rubber-covered flexible extension leads connecting the thermocouple to the instrument. Provision is also made for the user to attach a tee-handle if desired to facilitate manipulation of the thermocouple in the furnace.

The Brown system for molten steel temperature measurement is shown schematically in Figure 2. This system, which utilizes an indicating and recording ElectroniK Potentiometer and the new immersion thermocouple, provides closer control of melting and refining operations than previously possible. The "Continuous Balance" operating principle of the Brown ElectroniK has resulted in its being used in all branches of the steel industry, where accuracy, speed of response, and independence to the effects of dust, dirt, vibration, and ambient temperatures are important. Its large indicating scale, calibrated for this application with a temperature range of 2200 to 3200 F is visible for more than 60 ft.

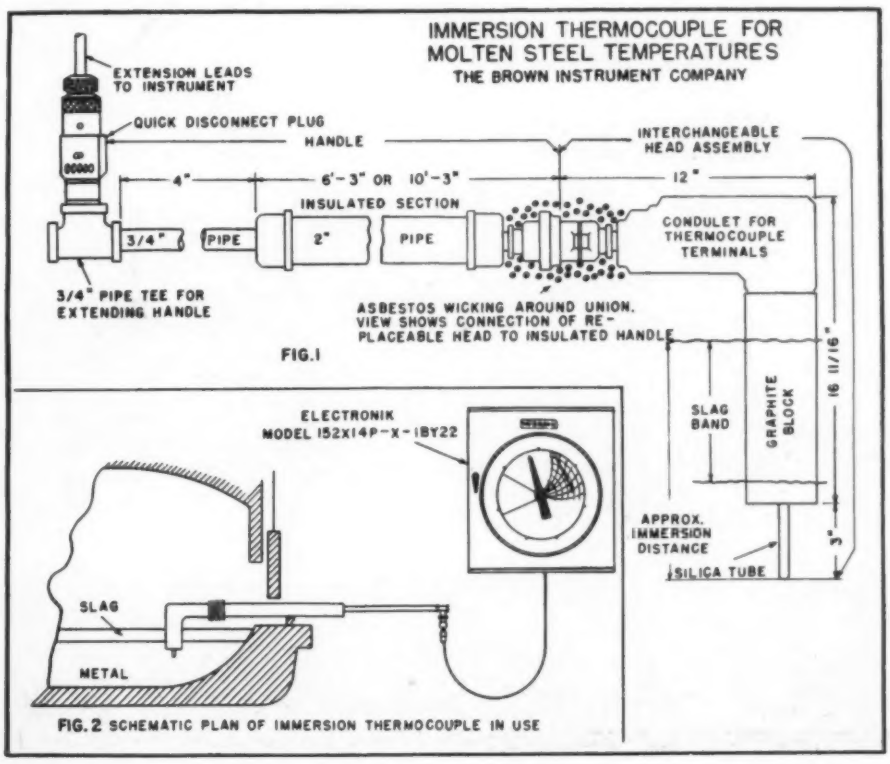
In the molten steel temperature measuring system, the ElectroniK is provided with a high speed chart drive, so that the circular chart makes one complete revolution in 4 minutes, and is provided with an automatic chart drive switch to start the chart in motion only when the thermocouple is immersed in the molten steel. These features provide maximum utility of the instrument under normal operating conditions. A detailed record of each temperature measurement is made, and as the time required for each measurement ranges from 30 to 45 seconds, a single chart will record as many as six heats, which is usually sufficient for a day's operation on one furnace.

Each step in the manufacture of the thermocouple wire is controlled with extreme care. The final product is carefully checked against government standards and has an accuracy of plus or minus 10 degrees at 2900 F.

Each 30-in. thermocouple coiled on the ceramic spool is sufficient for about 375 readings. After every sixth reading has been made, ¼-in. is cut off the tip of the thermocouple, the remaining wire checked for contamination, and a new tip welded, annealed, and calibrated. Thermocouple wire cut off the tip is salvaged. Thus, the operating cost of the thermocouple is extremely low.

The excellent heat transmission characteristics of fused silica in combination with carefully designed thermocouple components result in outstanding speed of response. The total time required for a complete temperature measurement is 30 to 45 seconds. The overall accuracy of the complete system is within 10 to 12 degrees at 2900 F.

Reference to Figure 1 shows the sound construction of the immersion head. Every component used in the assembly has been selected with the steel maker in mind. Given reasonable care, the thermocouple will provide years of satisfactory operation with a minimum of maintenance. In addition, the device is extremely portable. It is carried to the furnace when needed and replaced in a suitable rack or stand after use, requiring a minimum of floor space.



The immersion thermocouple has been proved by two years of continuous use in a steel melting shop to be a reliable and practical method of measuring the temperature of molten steel. The Brown ElectroniK used with the thermocouple is a tool for the melter and metallurgist. It has been applied to metallurgical research and in the field of electric furnace alloy steels has made possible extremely valuable data.

CARBON BRUSH REDUCES COMMUTATOR WEAR

▲ An exceptionally wide bend of commutation, high stability and long service life are among the advantages offered in a new carbon brush developed by the Speer Carbon Company of St. Marys, Pennsylvania, for many types of industrial electric motors and generators. Known as grade No. 4029, this new Speer brush has demonstrated its ability through tests to reduce commutator wear and maintenance. The maker also recommends it for generators and traction motor units on Diesel-electric locomotives. Grade No. 4029 is offered as a standard single piece brush or in the Speer "Multiflex" construction.

ELECTRONIC FINGER CONTROLS CUTTING

▲ An "electronic finger," which automatically controls the operation of a machine tool, has been developed by General Electric engineers.

From shaping graceful candlesticks to highly-essential superchargers for aircraft engines — it's all the same to a machine tool controlled by this new automatic contouring control system.

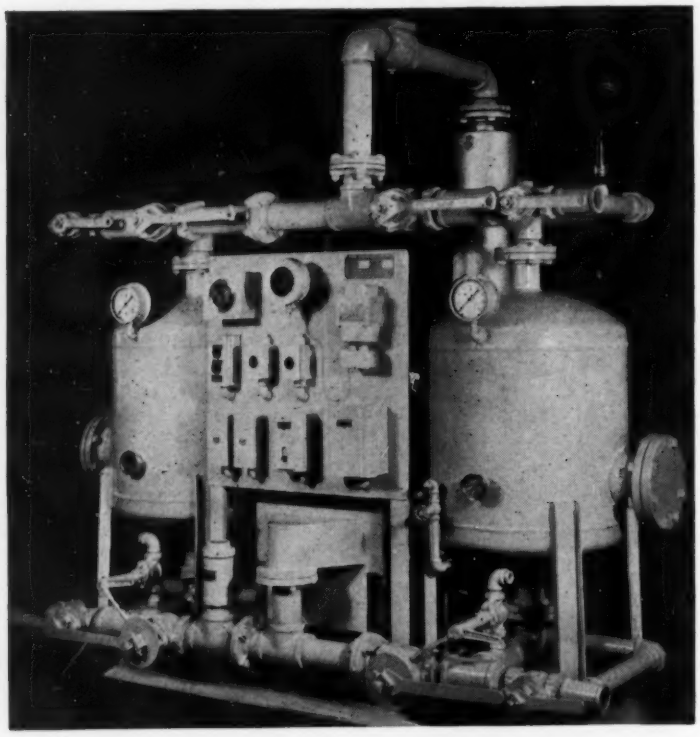
In fact, almost anything that can be cut with a motor driven tool from a pattern or template can be produced accurately and completely automatically with a machine equipped with this versatile device which literally has a "sense of touch."

The vital part of the "anatomy" of this human-like control device is an "electronic finger" which feels its way around the angles and curves of a pattern to control the operation of the cutting tool.

This feeler or tracing stylus comprises, in electrical terms, two magnetic bridges, each consisting of two identical magnetic circuits, one pair mounted on an axis at right angles to the other pair. The four magnetic poles are assembled on a diaphragm which is fastened to the stylus, a finger-like projection which touches the pattern or template.

The rapid changes in direction of machine motion are dependent on fast motor control. The thyratron tube, a General Electric development, provides the means for controlling motor speed and direction from the translator circuit signals — and almost instantaneously! So sensitive is the control over the motors, that each can be stopped or started in less than an eighth of a second.

Provisions are also made on the master control panel for remote non-automatic operation of the contour equipment. By merely pushing a button, an operator may release the automatic control and take over the operation of the machine himself. With this method, the speed, direction, and control of the motors are



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Kemp Dynamic Dryers are the answer to chemical process problems wherever moisture is detrimental.

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AIR • GASES • LIQUIDS

at pressures from atmospheric to 1500 lbs.

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INERT GAS PRODUCERS • FLASH ARRESTORS

"Our 11 BAKER TRUCKS have given us Continuous 24 hour service for 4 years"

Routine periodic inspection and lubrication pays substantial dividends in the operation of Baker Trucks at Thompson Aircraft Products Company's mammoth new Cleveland plant.

Here is a good example of what can be expected of Baker Trucks in the way of *continuous operation,* when properly cared for. According to N. J. Shibley, Superintendent of Building and Property Maintenance at Thompson, their Baker Crane Truck and ten Baker Fork Trucks are as good as new after serving three shifts per day for nearly four years—the equivalent of 12 years of normal service. No truck has been overhauled, there have been only a few minor mechanical failures, and maintenance has been almost negligible.

Actual time out of service averages less than ½ hour per day, per truck, divided as follows:

Daily check of Hydraulic System . . .	5 min.
Battery changes (2 min. each shift) .	6 min.
Weekly lubrication (45 min.)—per day	7 min.
Other maintenance (Tires, brakes, inspection and adjustment of electrical controls, etc.) 45 hrs. per month for 11 trucks—per day	10 min.
Total .	28 min.

Except for the above and for a ten minute period between shifts when trucks are idle, they have been giving "round-the-clock" service for four years and, says Mr. Shibley, "if we continue to take good care of them, they should last indefinitely." That's *Continuity!*

To help you keep your Baker trucks operating continuously and to insure long life, write for "Industrial Truck Care Pays You Dividends."

BAKER INDUSTRIAL TRUCK DIVISION
of The Baker-Raulang Company
2166 WEST 25TH STREET • CLEVELAND, OHIO
In Canada: Railway and Power Engineering Corporation, Ltd.

handled by the operator through a system of push buttons and dial controls on the master panel. This manual operation is particularly advantageous in following an outline pattern instead of a cutout template.

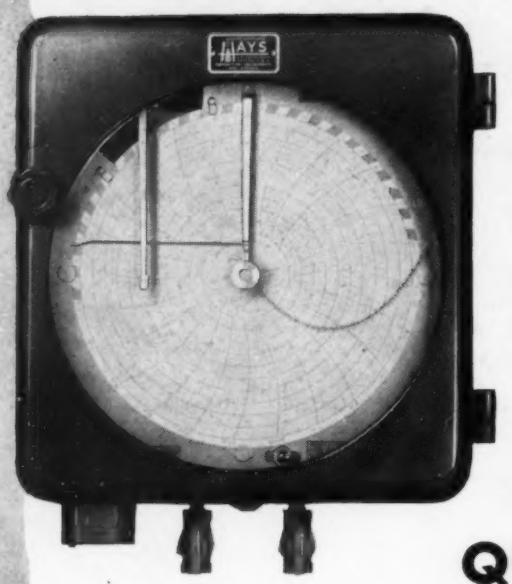
Extremely simple to operate, G.E.'s new control can be applied to many different types of metal cutting tools and is capable of a variety of intricate cutting operations, which, if done by complete manual operation, would involve many separate directional cuts and endless gage checks.

CROCKER-WHEELER ADDS THREE MOTOR SIZES

▲ With the addition of three new frame sizes, designated as B58-A, B and C, the Crocker-Wheeler Division of Joshua Hendy Iron Works, Ampere, New Jersey, now offers a complete line of alternating-current, squirrel-cage, protected type motors from 1 to 200 hp. Priced the same as the conventional open type and rated 40 C rise, full-load continuous duty, with a 15 per cent service factor, these motors provide full protection against dripping liquids, falling metal chips and other foreign matter.

Sizes built in NEMA standardized frames, 203 to 326 inclusive, have no openings in the frame or shields above the horizontal center line. NEMA standardized frames 326 to 505 as well as the three, newly added, larger sizes are basically the same in construction with the addition of two shielded, air exhaust openings in the upper half of the frame. The design of these openings precludes any possibility of falling liquids, etc., entering the motor.

For better steel.. and more of it



this recorder of facts *helps control* STEEL QUALITY

YOU find Hays Series "OT" Pressure Recorders on many new and modernized open hearth installations—and for just one purpose: to make a permanent record of furnace performance. Guesswork is eliminated, man power saved, and rejects cut to the minimum.

On the 10-inch 24-hour charts you can have a record of two draft values, two pressure values, two differential values or any combination of two of those three values.

Here's a simple practical means to more effective control of steel quality. Better get the facts about it—send for Bulletin 43-586.

The HAYS CORPORATION
COMBUSTION INSTRUMENTS AND CONTROL
MICHIGAN CITY, INDIANA, U.S.A.

HIGH NICKEL-BEARING STEEL USED IN TUBING

▲ A new application of the recently developed 9 per cent nickel steel in tubing designed especially for subzero temperatures was announced by The Babcock and Wilcox Tube Company, manufacturers of the new product. This is the first time that this high nickel-bearing steel has been made available in tubular form.

Developed primarily to answer the pressure tubing needs of plants handling liquified gases or other low temperature fluids, the new nickel steel tubing exhibits good physical properties even at temperatures as low as minus 320 F (minus 196 C).

According to H. D. Newell, Chief Metallurgist and Director of the Tube Company's laboratory, the new product may be applied in low temperature work as a substitute for 18-8 stainless steel tubing, and it will have particular applications in oil refineries and the chemical industries. It is also probable that it can be used for special pump tubing in oil wells where salt water and hydrogen sulphide in the oil fluid present a difficult corrosion problem. Other applications are in the tubes for black liquor evaporation (in the preparation of waste black liquor for burning in the Kraft paper industry), for caustic solution evaporation, and for alkaline-phenol solution work.

The new 9 per cent nickel steel tubing is capable of giving Charpy impact values as high as 25 foot pounds, even at the minus 320 F temperature. The new alloy will offer resistance to attack by alkaline media and to low temperature embrittlement to a greater degree than any other nickel alloy steel tubing regularly produced by the company.

QUELARC

The circuit breaking plugs and receptacles . . . ratings up to 200 amperes

Pyle-National plugs and receptacles are built to stand up in mill service, delivering dependable service with minimum maintenance. The exclusive QuelArc construction provides exceptional protection to contacts, for safe use as current rupturing devices. In the section view, note the complete enclosure of all contacts in insulating chambers which form an arc-trapping space. Note also the long distances from contact to contact and from contacts to ground. Contacts are individually renewable. Full ground protection is provided.

QuelArc plugs and receptacles are available in a complete range of styles, 2, 3, 4 wire types; ratings 20, 30, 60, 100, and 200 amperes. Many other types available for portable tools and control and instrument circuits. Write for general catalog 1100 with listings of all types.

THE PYLE-NATIONAL COMPANY
1334-58 North Kostner Avenue • Chicago 51, Illinois
Offices: New York, Baltimore, Pittsburgh, St. Louis, St. Paul, San Francisco

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ELECTRICAL EQUIPMENT
• SINCE 1897 •

CONDUIT FITTINGS • FLOODLIGHT PROJECTORS • LOCOMOTIVE ELECTRICAL EQUIPMENT

New Literature

▲ Principles of Industrial Process Control, published by John Wiley & Sons, Inc., New York, explains automatic control, measurement and process in a language that is understandable to the student and worker and valuable as a guide and reference for the processor and his technicians.

Written by Donald P. Eckman, engineer of Brown Instrument Company, industrial division of Minneapolis-Honeywell Regulator Company, the book is the first of its kind to be published concerning the overall basic fundamentals of the science of automatic industrial control.

Subjects covered include: Measuring means of industrial controllers, characteristics of measuring means, modes of automatic control, final control elements, process characteristics theory of automatic control, quality of automatic control, application of control engineering, automatic control systems, maintenance of exact control. The volume ends with a glossary of 126 terms and definitions. It also provides 119 references.

Under related headings the author has considered the various elements of error and lag, methods of regulation, cycling, pressures, humidity and air conditioning, maintenance and upwards of 150 other sub-basic principles.

Primarily, the volume is intended for the student in chemical, metallurgical, mechanical or electrical engineering. The growing importance of this subject to modern industrial processing has been acknowledged by the addition of courses in instrumentation and automatic control to the curricula of engineering colleges and technical schools.

▲ Entirely revised to include the latest data on new arc welding methods and equipment, the eighth edition of the "Procedure Handbook of Arc Welding Design and Practice" has just been announced by the publishers.

Special effort has been made by the authors to provide complete information to help those in all fields of industry obtain the greatest possible benefits from the process of arc welding in the design and construction of various parts and products and in the use of the process as a maintenance tool.

This new edition of the book carries many new illustrations, covering significant welding applications developed in various phases of war production which heretofore have not been published due to restriction.

In addition to standard data on welding symbols, speeds and costs, characteristics of metals, pre-heating, stress relieving, approach to welded design and other pertinent information, the newly revised Handbook includes 1312 pages, 6x9 in., and costs $1.50 in the United States, and $2.00 elsewhere. The Lincoln Electric Company, Cleveland, Ohio, are the publishers of the book.

▲ A completely revised edition of Airco's popular "New and Improved Oxyacetylene Methods for Steel Foundries" is now being distributed by Air Reduction, New York City.

This 30-page illustrated booklet contains descriptive information concerning the Airco-developed oxyacetylene processes which are now speeding production and reducing costs in steel foundries throughout the country.

The booklet demonstrates the advantages of machine flame cutting in the removal of risers, gates and sprues. It also describes three other fast and economical oxyacetylene applications developed and perfected by Airco: flame scarfing to remove padding left where risers have been removed, flame gouging for the removal of webs, fins, and defects, and flame descaling of normalized and annealed castings.

In addition, several sections are devoted to the expanded use of oxygen lancing to start openings and of flame hardening for quick, localized surface hardening of castings.

Copies of this booklet are available upon request to Air Reduction Sales Company, 60 East 42nd Street, New York 17, New York, or to any local Airco office.

▲ A new catalog No. 2010-B has been issued by the Heavy Machinery Division of The Cleveland Crane and Engineering Company, Wickliffe, Ohio, describing Cleveland Steelweld bending presses and bulldozers. Details of construction are illustrated and tables of dimensions and specifications included. Data are also provided on special bed and ram designs.

Cleveland Steelweld presses are available in 29 different sizes for bending, forming, drawing and multiple-punching plate from light gauge to one inch thick, and for lengths up to 20 feet. Steelweld bulldozers are available in sizes up to 220 tons bending capacity.

The Cleveland Crane and Engineering Company will be glad to furnish copies of catalog No. 2010-B upon request.

▲ A booklet, "Corrosion-Resistant Masonry Material and Construction Manual," has been released by The U. S. Stoneware Company, Akron, Ohio.

Prepared by the engineering staff of U. S. Stoneware, Bulletin 810 is full of helpful facts and suggestions pertaining to materials and construction methods for tanks, towers, sumps, floors and other masonry construction.

▲ The Industrial Finishing Division of the McAleer Manufacturing Company, Rochester, Michigan has just issued a new, illustrated, 24-page industrial finishing reference manual on "Polishing, Buffing and Deburring."

Among the finishing materials listed in this catalog are those old "standbys" of prewar days which have been retained because of proven usefulness and new finishing compositions developed for postwar production finishing needs.

For the man who uses or specifies industrial finishing materials, this booklet tells when and where to use what compositions, summarizes and interprets applications — offers helpful suggestions for present-day finishing of all types of metals, non-metals and plastics.

The McAleer catalog is free and available to all qualified industrial finishing material users. To secure a copy, write Industrial Finishing Division, Dept. P-1, McAleer Manufacturing Company, Rochester, Michigan.

▲ Wheelco Instruments Company, Chicago 7, Illinois, has issued a new edition of its Thermocouple Data Book and Catalog. Containing 32 pages and designated Bulletin S2-6, it gives information on selection of proper thermocouples and carries installation aids. It describes and lists prices and recommendations on thermocouples, thermocouple wire, lead wire, heads, connectors, plug and socket assemblies, insulators, and protecting tubes.

▲ A new 28-page book, describing P&H grab bucket cranes which are

Reaming in structural steel work has its hazards because the men often work high above ground with narrow steelwork as their only support.

Reaming with an air-operated Impact Wrench is safe and easy. The wrench is light enough to be used in all positions. The torque on the operator is so slight that in most cases the dead handle is not used. The steel worker can easily operate this tool with one hand. When finished, he removes the reamer and uses the same wrench to bolt up.

The rotary impact action of the I-R Impact Wrench is ideal for reaming and produces a clean hole free from chatter marks. Reamers can be easily fitted to the wrench chuck by simply slipping one or two nuts, of the size used on the job, over the reamer shank, welding them fast and cutting off any projection.

Some contractors have reported that by using the Impact Wrench to do both operations, reaming and bolting-up time has been cut in half.

COMPRESSORS
TURBO BLOWERS
OIL AND GAS ENGINES
CENTRIFUGAL PUMPS
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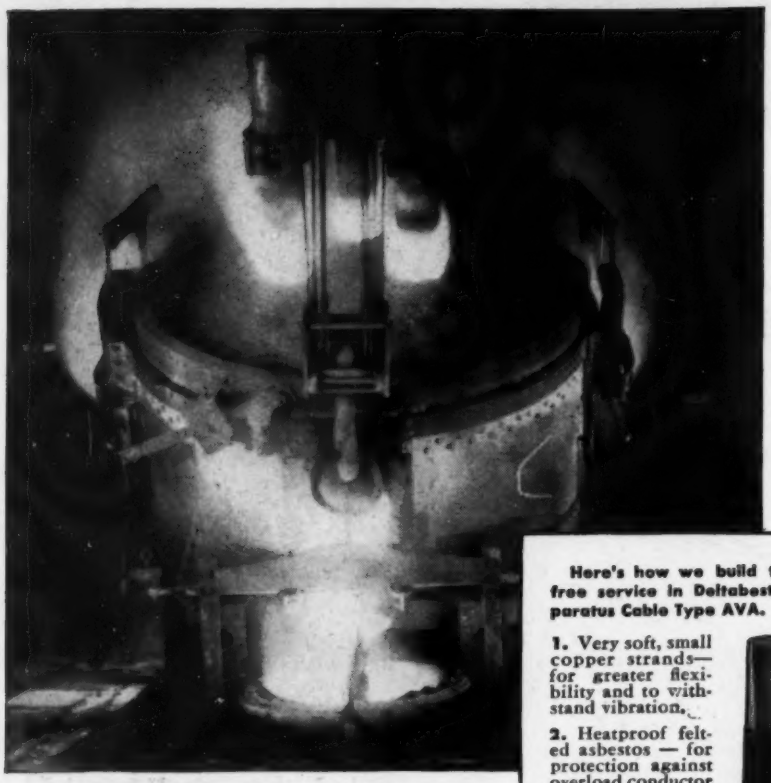

Here's how we build trouble-free service in Deltabeston Apparatus Cable Type AVA.

1. Very soft, small copper strands—for greater flexibility and to withstand vibration.

2. Heatproof felted asbestos — for protection against overload conductor heat.

3. Varnished cambric—for moisture resistance and high dielectric s.rength.

4. Felted asbestos —for extra protection against high ambient temperatures.

5. Asbestos braid —for high resistance to heat, moisture, oil, grease and most corrosive vapors.

Deltabeston Cables Withstand High Heat

Electrical circuits that run around boiler rooms, steam tunnels, soaking pits, pouring ladles and other hot spots are bound to fail frequently unless cable insulations can withstand high operating temperatures. One of the safest ways to provide uninterrupted electrical service in these torrid zones is to protect with Deltabeston Asbestos-insulated Power and Motor Lead Cables. These heat-resistant cables have proved in countless installations that the asbestos-insulation just won't bake out despite constant, high heat.

Is excessive heat is causing frequent power failures in your mill, investigate G-E Deltabeston Asbestos-insulated Cables now. Deltabeston is used extensively for power, lighting and control circuits especially where severe operating conditions prevail. General Electric manufactures a complete line of asbestos-insulated cables including many special designs. They're constructed not only to withstand excessive heat but high humidity, oil, grease and most corrosive vapors.

For additional information write to Section Y1253-51 Appliance and Merchandise Dept., General Electric Company, Bridgeport, Conn. Deltabeston Wires and Cables are distributed nationally by Graybar Electric Co., General Electric Supply Corp., and other G-E Merchandise Distributors.

GENERAL ELECTRIC

built for service on all types of jobs, large or small, has been issued by the Harnischfeger Corporation. Construction details are given, and various industrial applications are illustrated. Particularly suited for handling all types of bulk materials such as ores and solid fuels, these cranes are widely used in metal working industries. This book is available on request. Write the Harnischfeger Corporation, Milwaukee 14, Wisconsin. Ask for Bulletin C9-1.

▲ A new bulletin on "Ellpro Cutting Electrodes," for underwater or surface cutting, has been published by Ellwood Products Corporation.

These highly efficient cutting electrodes were developed by Ellwood engineers and the U. S. Naval Experimental Sation at Annapolis. With the end of the war, the possibilities for Ellpro cutting electrodes in harbor clearance, salvage and certain construction operations can now be revealed.

The new bulletin on Ellpro cutting electrodes gives complete details and specifications, together with a fully illustrated description on how to use the electrodes. The bulletin also describes the Palmgren arc oxygen kit for underwater cutting, used with Ellpro cutting electrodes. Copies of the bulletin are available direct from Ellwood Products Corporation, Ellwood City, Pennsylvania.

▲ The B. F. Goodrich Company, Akron, Ohio, has just published an attractive and well-illustrated 38-page booklet on industrial tires under the title "How to Save Money on Industrial Hauling Jobs and Equipment." Copies are available upon request to the company.

The booklet opens with a discussion of how rubber industrial tires give six-way savings to users, less hauling time, floor wear, noise and depreciation, reduced breakage and fewer accidents. It then follows with a description of scientific tests which prove that rubber tires do possess these advantages. Care and maintenance of industrial tires is another featured section.

Description with text and pictures of each industrial tire is followed by complete data. Ten pages are devoted to specifications for a partial list of power trucks and tractors by United States manufacturers, with the model, type, truck capacity, and tire sizes listed.

WAR-WIRED CIRCUITS

Prematurely Aged

by 12 years of severe service

You will probably grant that 3 or 4 years is more than a normal dependable lifetime for wire and cable operating in hot spots or under other severe conditions . . . but if you multiply by 3 the number of years your war-installed circuits have been in service you'll get a better idea of just how old they really are.

Another point to remember is that this *premature aging* was accelerated beyond calculation by 'round the clock year-to-year operation *without rest cycles.* All of which adds up to a lot of wire-failure possibilities in circuits that run around steam lines, furnaces, lehrs, annealers, soaking pits, or in boiler rooms, blooming mills or steam tunnels . . . power, control and lighting circuits that you may still consider too new to fail although *they are already prematurely aged and unsafe!*

And don't forget that a lot of the wire you put in when you had to take anything you could get wasn't built to take the kind of service it had to stack up against . . . so for safety and uninterrupted service take a survey of your trouble spots and rewire with *permanently insulated* Rockbestos A.V.C. 125 different standard constructions and National Electrical Code approved types to select from. For a catalog or information write to the nearest branch office or:

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The Wire with Permanent Insulation

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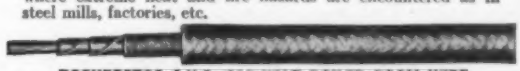
LOS ANGELES SAN FRANCISCO SEATTLE PORTLAND, ORE.

ROCKBESTOS A.V.C. 600 VOLT MOTOR LEAD CABLE
(National Electrical Code, Type AVA—max. operating temp. 110°C.)

Size No. 18 AWG to 1,000,000 CM insulated with two walls of impregnated asbestos and a high-dielectric varnished cambric insert, with a heavy asbestos braid overall.

Heatproof, fireproof and resistant to moisture, grease and oil—like the power cable pop Time is standing on—will not dry out and crack, won't burn or carry flame and remains permanently flexible. For coil connections, motor and transformer leads where extreme heat and fire hazards are encountered as in steel mills, factories, etc.



ROCKBESTOS A.V.C. 600 VOLT BOILER ROOM WIRE
(National Electrical Code, Type AVA—max. operating temp. 110°C.)

Sizes No. 18 to 8 AWG insulated with varnished cambric, impregnated felted asbestos and asbestos braid. Sizes 6 to 4/0 have another wall of impregnated asbestos next to the conductor.

For lighting and control circuits exposed to heat and moisture, oil, grease, corrosive fumes or fire hazard, such as exist around furnaces, ovens, lehrs, soaking pits, boilers, etc., this widely used A.V.C. construction is ideal. Its permanent insulation will not bake brittle, crack, rot, flow or swell.

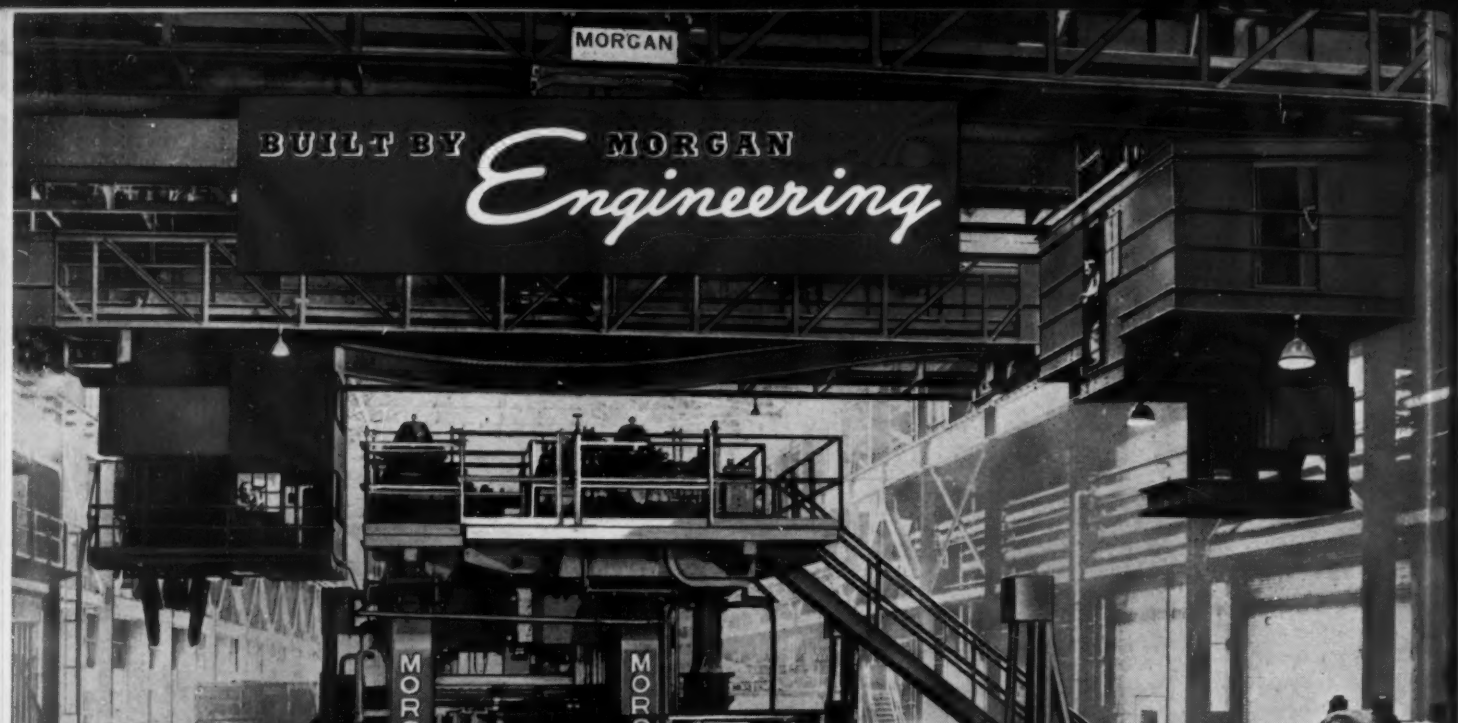
ROCKBESTOS A.V.C. 600 VOLT SWITCHBOARD WIRE
(National Electrical Code, Type AVB —max. operating temp. 90°C.)

Sizes No. 18 to No. 4/0 A.W.G. with varnished cambric and felted asbestos insulation and gray, black, white or colored flame-proof cotton braid.

Combine fire insurance and fine appearance in your switchboards with Rockbestos Switchboard Wire. It is absolutely fireproof and will not dry out under heat. Sharp, clean bends can be made without cracking as the asbestos wall acts as a cushion under the braid. Rockbestos A.V.C. Hinge Cable and Switchboard Bus Cable have the same fireproof and heatproof characteristics.

Another New Rockbestos Firewall Construction—A 400°F. Wire!

War-developed Rockbestos High-Temperature Wire —*with a maximum operating temperature of 400°F.*— designed for jet propelled plane applications and circuits to hot-wing de-icers, fire detectors and extinguishers, and air conditioning and heating units where baking temperatures destroy ordinary insulation. Under continuous operation at rated temperature it retains its original dielectric strength and inherent resistance to heat and flame, and *progressively improves* in its resistance to moisture and abrasion. Now available for these and other severe applications. Write for complete information and samples.



MORGAN "36" TWO-HIGH BLOOMING MILL

GROUPED OVER THE MILL IS A MORGAN 7½-TON SOAKING PIT CRANE AND A MORGAN 200-TON 81'-3" SPAN UNIVERSAL TYPE INGOT STRIPPER

With this Mill was furnished Auxiliary Equipment as follows — Front and Rear Tables with Manipulator — Approach Table — Ingot Buggy — Runout Tables — Slab Shear with Gauge — Crop Hoist — Pushers — Conveyor — Skid Bed and Furnace Tables.

Above is shown a Morgan 36" two-high blooming mill complete with double manipulator, front and rear tables. Three mills of this type were recently furnished prominent mid-west steel producers. Housings are one-piece steel castings of the closed top type. Top roll balance is of the counterweight type.

Manipulator is of the overhead type, compact and accessible. Tables are of heavy design, equipped with anti-friction bearings. Screw-down drive is arranged to provide crane hook access when changing guides. Provision is made for automatic lubrication and exclusion of scale and dirt.

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Personnel News

Stephen B. Metcalfe has been named special engineer in charge of rope plant development for the American Steel and Wire Company and will be located in the chief engineer's office in Cleveland, Ohio. **A. J. King** has been appointed general superintendent of the New Haven and Trenton Works and will center his activities at New Haven. At the same time, **Charles R. Chase** has been made superintendent of the Trenton Works, succeeding Mr. King.

Mr. Metcalfe has been employed by the wire company since January, 1929, having started at the New Haven Works as a foreman in the wire drawing department. He held a number of positions in New Haven before being transferred to Trenton in August, 1938, as superintendent of that plant. Since January, 1942, he has been general superintendent of the New Haven and Trenton Works.

Mr. King's service with the wire company extends back to January, 1922, when he was hired as a rope machine operator at New Haven. He held a variety of positions in the production and sales promotion of wire rope at New Haven, Worcester, Massachusetts, Cleveland, Ohio, and Chicago, Illinois. before being transferred back to New Haven as chief rope engineer in September, 1939. In January, 1942, he was appointed superintendent at Trenton, which position he has held to the present time.

Mr. Chase was first employed by the American Steel and Wire Company in June, 1916, as a tester at Central Works in Worcester. Following a 15-month period of service in the U. S. Marine Corps in World War I, he returned to the wire company and worked his way up through the ranks, being appointed superintendent of the wire department at Trenton in August of this year.

Alexander S. Findlay, who for many years was chief electrical engineer, Youngstown district, Carnegie-Illinois Steel Corporation, has joined the Crocker-Wheeler Division of Joshua Hendy Iron Works, Pittsburgh district, in an engineering sales and service capacity.

Mr. Findlay is a graduate of Carnegie Institute of Technology and a member of the National Society of Professional Engineers and has been identified with a great number of major engineering projects.

E. U. Lassen has been appointed assistant chief engineer for Cutler-Hammer, Inc., Milwaukee, Wisconsin.

Mr. Lassen, a native of Norway, obtained his technical education at the Federal Institute of Technology, Zurich, Switzerland, receiving the degree of Electrical Engineer in 1923. The following year he came to the United States and joined the Cutler-Hammer organization as a draftsman. Later in 1924 Mr. Lassen transferred to the company's engineering department as a designing engineer. In 1930 he was made an engineer supervisor and in this capacity his responsibilities reached into many different divisions of the company's activities.

Adam J. Hazlett, of the Jones and Laughlin Steel Corporation was elected a director and member of the executive committee by the board of directors. He has been vice president in charge of sales since July 27, 1944 and has been with J & L since 1938 when he came to the company as manager of the strip-sheet sales department. Mr. Hazlett, after graduation from college, was employed by West Penn Steel Company in the operating and sales departments; later became sales manager and then president of Eastern Rolling Mill Company, which position he held until he came with Jones & Laughlin.

J. L. Singleton has been appointed manager for the 60 district offices of the Allis-Chalmers general machinery division's sales department, announces **William C. Johnson,** vice-president.

Assistant manager of the steam turbine department prior to his appointment, Mr. Singleton joined Allis-

ALEXANDER S. FINDLAY

E. U. LASSEN

J. L. SINGLETON

Cranes represent an important durable goods investment, anticipating long care-free service as exemplified by the Hyatt equipped units built by the Whiting Corporation.

The reason Hyatt Roller Bearings have been and continue to be the outstanding choice for cranes, trolleys and hoists is because they measure up to the three essential requirements:—rugged durability—simplicity—and minimum of maintenance required.

Millions of rollers roll in Hyatt Roller Bearings throughout all industry, agriculture and transportation. If you have a bearing problem why not discuss it with Hyatt engineers?

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FRANK W. KELSEY

H. J. GRIFFITH

Chalmers in 1926 after receiving a B.S. degree in mechanical engineering from Alabama Polytechnic Institute. He was granted a leave of absence to work as a power plant engineer for a large Chicago firm in 1928, returned to the Allis-Chalmers Denver district office, and was made district office manager there in 1938. Mr. Singleton was transferred to the West Allis works as assistant to the manager of the steam turbine department in 1942 and became assistant manager seven months later.

H. J. Griffith has been appointed assistant to the general superintendent of the Vesta-Shannopin Coal Division of the Jones and Laughlin Steel Corporation. Prior to his present appointment, Mr. Griffith was manager of safety and welfare for Jones and Laughlin.

Frank W. Kelsey succeeds Mr. Griffith as manager of safety and welfare. He was formerly superintendent of safety and welfare at the J & L Aliquippa Works.

J. B. Laird of Laird and Johnson, Union Trust Building, Pittsburgh, Pennsylvania, has retired from active business effective November 1, 1945.

R. T. Johnson will continue as Johnson Machinery Sales, Union Trust Building, Pittsburgh, Pennsylvania, to handle Northern Engineering Works products, consisting of electric overhead traveling cranes and electric and air operated hoists. Mr. Johnson will also represent the Hill Acme Company, Canton Division, who manufacture alligator shears, portable cranes and special machinery.

R. C. Talbott recently plant engineer at Salt Lake City, Utah, for the Geneva Steel Company, is now associated with the H. C. Frick Coke Company, Uniontown, Pennsylvania as construction engineer.

Charles Schenck, engineer of development, Bethlehem Steel Company retired on October 31.

Mr. Schenck studied civil engineering at the University of Illinois. He was employed by Chicago firms until 1901 when he was made an instructor at the Lewis Institute, Chicago, now the Illinois Institute of Technology. He became superintendent of the car shops of the Chicago Railways Company in 1908, continuing there until 1910.

In 1910 Mr. Schenck became works manager and chief engineer of the Elevator Supply Company of Chicago and Hoboken, New Jersey, and in 1916, works manager for Budd Wheel Company of Philadelphia.

Mr. Schenck left the Budd Company in 1918 to become production engineer with Bethlehem Steel Company at the Bethlehem plant. He remained in this position until 1934, when he was appointed engineer of development in the development and research department.

Maynard R. Born, former engineer with the Columvia Steel Company at San Francisco, California, has recently accepted a position as engineer in the chemical division of Shell Oil Company, Inc., Houston, Texas.

Dr. W. R. Lankford, Jr., has been appointed development engineer in the research and technology department of Carnegie-Illinois Steel Corporation. He succeeds **Dr. J. R. Low, Jr.,** who has been appointed head of the department of metallurgy at Penn State College.

A native of Tennessee, Dr. Lankford earned his doctor of science degree in metallurgical engineering at Carnegie Tech. He was a teacher's assistant at Carnegie Tech from 1941 to 1943 and was a research metallurgist there from 1943 until last May when he went to Penn State in the same capacity. He will specialize in research regarding the mechanical properties of metals.

Dr. Low will continue with the Carnegie-Illinois research division as a consultant. He is a native of Washington, Pennsylvania and was an assistant professor of metallurgy at Penn State before joining Carnegie-Illinois.

E. G. Puttnam is now associated with the Kaiser Engineers at Oakland, California. Mr. Puttnam was formerly with the Carnegie-Illinois Steel Corporation, Clairton, Pennsylvania, as design engineer.

We are sometimes asked what is the secret of the materially increased production, improved quality and lower unit cost resulting wherever F. E. I. direct fired furnaces are installed.

No one feature accounts for it all—it's a combination of engineering skill, combustion know-how, new principles, and careful manufacture. These, taken together, make up the F. E. I. direct fired system —a system showing tangible and profitable advantages in every installation made to date.

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Direct Fired Cover Annealing Furnaces, for coiled strip, tin plate, flat sheets, wire and rod.

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Galvanizing Furnaces for pipe, sheets and job shops.

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Louis T. Barry has been appointed manager of the power and industrial division of the Electric Service Manufacturing Company, Philadelphia. Prior to service in the armed forces as lieutenant colonel, Mr. Barry was manager of the Pittsburgh office of the company. He will now be located in Philadelphia headquarters.

Dr. William T. Griffiths, of London, has been elected a vice president and director of The International Nickel Company of Canada, Limited. In both these offices, he succeeds the late David Owen Evans, Liberal member of Parliament for Cardiganshire, North Wales, from 1932 to the time of his death on June 11, last.

Dr. Griffiths is chairman of The Mond Nickel Company, Limited, the British affiliate of International Nickel. Joining Mond in 1926, Dr. Griffiths had been manager of its development and research department since 1928. He is president of the Institute of Metals of Great Britain.

Charles H. Jennings, director of welding research for the past nine years, becomes engineering manager of the welding department in the motor division of the Westinghouse Electric Corporation. **John H. Blankenbuehler** is made manager of arc welding apparatus, **while E. Hill Turnock, Jr.,** is made manager of arc welding electrodes.

Born in Des Moines, Iowa, Mr. Jennings received a Bachelor of Science degree in mechanical engineering from Iowa State College, at Ames. He enrolled in the Westinghouse Graduate Student Course upon graduation in 1928. and was assigned to the mechanical division of the research laboratories. He was transferred to the chemical and metallurgical division of the laboratories and took charge of all welding research in 1936.

In 1937 Mr. Jennings was called to England as consultant welding engineer for the English Electric Company, and in the same year supervised all electric welding on the famed Westinghouse "atom-smasher." He was awarded the Company's Order of Merit for distinguished service in welding research and application.

A native of Elizabeth, Pennsylvania, Mr. Blankenbuehler was graduated from Lehigh University, Bethlehem, Pennsylvania, in 1923 with a degree in electrical engineering. He joined Westinghouse immediately as a student in the training course, became a design engineer, and has specialized in the design and development of welding apparatus and equipment. Mr. Blankenbuehler was awarded the Company's Order of Merit in 1936 for his outstanding engineering work in the development of welding apparatus.

Born in La Grange, Illinois, Mr. Turnock attended the University of Wisconsin and Carnegie Institute of Technology, receiving his Bachelor of Science degree in chemical engineering in 1918. He served as a second lieutenant in the Army Engineers in France during World War I. Joining Westinghouse in 1926 as an insulation engineer, he was assigned to the development of welding electrodes a decade ago. Mr. Turnock, who won the Company's Order of Merit award last year, is a member of the American Welding Society.

J. D. Eby, manager of purchases of the Wagner Electric Corporation was elected to the secretaryship of the company on September 26, 1945, filling the va-

HOW L-R COUPLINGS ARE

Saving Shutdowns

In L-R Resilient Alignment Couplings, half the load cushions are idlers (except on reversing load). Hence there is always a new set of cushions in the coupling. This eliminates shutdowns, as cushions can be quickly interchanged without tearing down coupling.

L-R FLEXIBLE COUPLINGS

- Correct for misalignment.
- Take up shock and vibration.
- Have greatest flexibility.
- Need no lubrication.

Here is an L-R of most rugged construction for hard and heavy duty — 2 to 2500 h.p. Individual free-floating load cushions between metal jaws, are free instantly to adjust to any emergency. Cushions are always in sight for inspection. Leather, rubber duck, armored rubber, etc., — material best adapted to particular service.

There's an L-R for every requirement from 1/6 to 2500 h.p.

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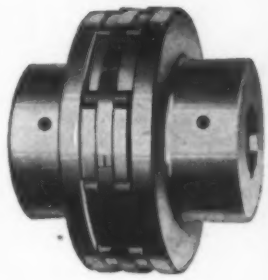
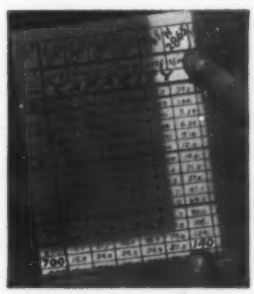


Pat. and Pats. Pending



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The juggler's control is easier of achievement if the objects being tossed are identical in every way.

His choice, in this case, is a happy one because "Link Control" is the guarantee that each piece is identical with its neighbor.

The "control" exercised at our mines, in the selection of raw material, is "linked" to the "control" practiced at each stage of manufacture. Each inspection is another link in the chain. With "Link Control" on the job you get every piece to exact specification.

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cancy created by the death of the former secretary, **J. W. Westcott,** on July 20, 1945. Mr. Eby assumes these new duties in addition to his present responsibilities as manager of purchases.

Mr. Eby began his apprenticeship with the Wagner Company in 1906. He was made production manager in 1912. In 1916 he transferred to the purchasing department and has been manager of purchases for a number of years.

In addition to managing the company's huge wartime purchases, Mr. Eby participated in many war activities. He served various governmental agencies concerned with priorities and material controls; was an automotive industry advisor to WPB; Washington chairman of the material control committee of the Automotive Council for War Production; and during 1942 he served on one of the NEMA committees dealing with war production.

K. G. Baker is back with Wagner Electric Corporation (Indianapolis Office) as a field engineer after over three years' active duty with the army. Mr. Baker is a veteran of both world wars, having served overseas both times. Mr. Baker's record with Wagner dates back to March 1, 1929, when he joined the company as sales-engineer, working out of their Cincinnati office. In the fall of 1931, he was transferred to the Indianapolis office which was his headquarters until he returned to the army in 1942.

ROBERT M. HATFIELD

Robert M. Hatfield has resigned as deputy vice chairman of the war production board to become assistant general sales manager of Combustion Engineering Company.

A mechanical engineering graduate of Purdue University, class of 1932, Mr. Hatfield came with Combustion Engineering Company in 1934 as a student engineer, subsequently serving in the service and erection department, the proposition department and then as sales engineer in the Cleveland office. In 1942 he went to Washington as chief of the boiler section of the power branch, WPB under **J. E. Krug** and later became director of the production scheduling division.

He resigned from WPB in May 1944 to accept a commission in the navy, and in November of that year was assigned back to WPB to take charge of the navy

repair parts program. Last April he was placed on inactive status by the navy to become deputy vice chairman for production of WPB which position he held until the war production board was abolished on November 2, 1945.

James E. Lounsbury, Jr., has joined the editorial staff of "Industrial Heating", Union Trust Building, Pittsburgh, Pennsylvania. During the past five years he was associated with the chemical laboratories and metallurgical departments of the Jones and Laughlin Steel Corporation at its Pittsburgh Works.

Luther D. Shank has been appointed Philadelphia district manager, with offices at 1217 Race Street, Philadelphia 7, Pennsylvania, for the Appleton Electric Company of Chicago, Illinois.

Mr. Shank comes to this new connection from the war production board where he was chief of the electrical materials section. Prior to going to the war production board in 1942, Mr. Shank was associated with the middle department, National Board of Fire Underwriters, Philadelphia.

William A. Davidson has been appointed Pittsburgh district manager, with offices at 418 Bessemer Building, Pittsburgh 22, Pennsylvania.

Mr. Davidson, who is an alumnus of Temple Universith, has been engaged in sales activity in the electrical field in Pittsburgh for the past five years and replaces **C. L. Snyder** who has retired.

George K. Bradfield, Jr., has been appointed an assistant vice president of American Car and Foundry Company. In his new capacity Mr. Bradfield will assist **E. D. Campbell,** vice president in charge of engineering.

Mr. Bradfield was born in New York. He graduated from Stevens Institute of Technology in 1922 with the degree of mechanical engineer. He immediately became associated with the Public Service Gas and Electric Company of New Jersey. He came to American Car and Foundry Company in 1933 to work in the New York engineering department; and in May 1939 he was transferred to the ACF Berwick, Pennsylvania plant to assist in passenger car design.

When the company entered upon its vast war work, Mr. Bradfield's services were utilized to the fullest extent by the ordnance division of ACF which was to engage in building light combat tanks for the U. S. Army. Mr. Bradfield served as general superintendent of ordnance for the company and in 1943 when other manufacturers began to build the light tank, he was transferred to Detroit as liaison with other companies and army ordnance on the light combat tank. In February 1944 he returned to New York as assistant director of research and continued in that post until his recent appointment.

Peerless engineering is precision engineering that permits closer tolerances which eliminate the customary vibration to an unusual degree. Thus, wear and tear are reduced; repair bills consequently are the lowest known. The most vital parts of a Peerless Pump are doubly protected . . . by a Double Seal and Double Bearings . . . plus rugged construction . . . that more than double the productive life of the pump.

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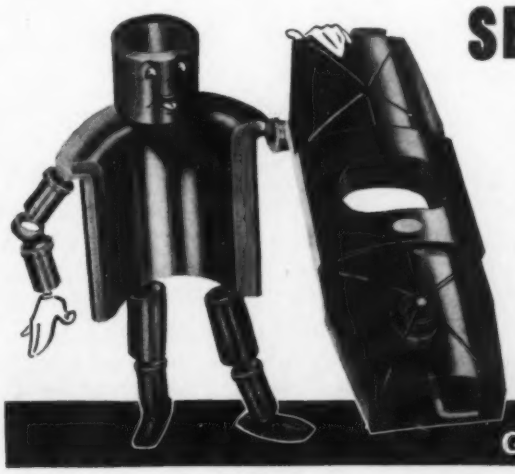

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The GATKE Invention that Revolutionized Universal Coupling Performance . . .

- **10 times longer service.**
- **Eliminate Socket Scoring and Wear.**
- ***Avoid costly machine shop work.***
- **End destructive vibration.**
- **Stop pounding noises.**
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- **Made to fit without machining for all sizes and types of UNIVERSAL COUPLINGS.**
- **Information on request.**

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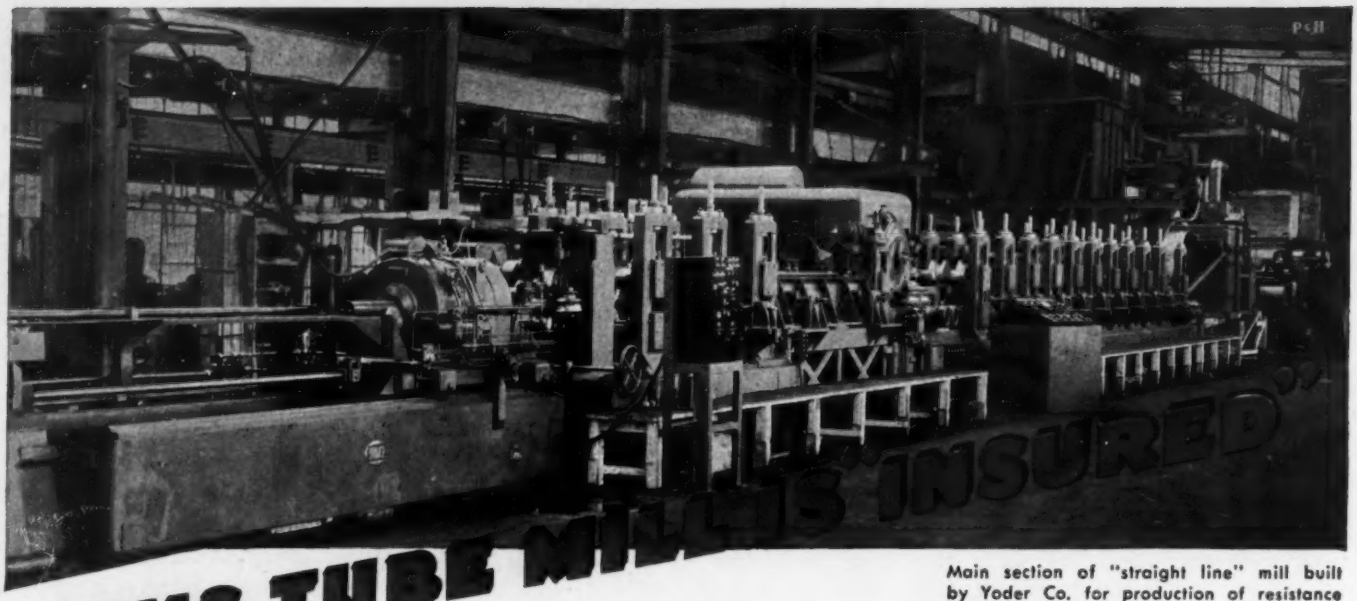
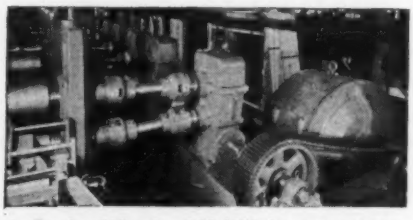


THIS TUBE MILL IS "INSURED" AGAINST MOTOR FAILURE

Main section of "straight line" mill built by Yoder Co. for production of resistance welded steel tubing at a rate of 65 to 85 feet per minute, from coils of unpickled, hot rolled stock.

One of the two Crocker-Wheeler 3/5 hp motors driving the conveyor section of the Yoder tube mill.



A Crocker-Wheeler 150/200 hp motor drives the forming mill section.

This Yoder electric-weld tube mill is a line of separately driven machines, all perfectly synchronized and so interdependent that the failure of any one of the driving motors would stop the whole mill.

Continuity of operation is "insured" against failure by the anti-breakdown design and construction of the Crocker-Wheeler motors that power the successive tube-making steps. Here are four of the protective features that assure trouble-free, long-term service from the 47 Crocker-Wheeler motors used in the mill.

1. Patented bearing seals permit use of softer grease, for better lubrication and longer bearing life. Bearings require re-greasing only once a year or even less frequently.

2. Varnish treatment of windings reduces hot-spot temperatures and lengthens insulation life. Prevents vibration of motor windings.

3. Dynamic balancing of squirrel-cage rotors and d-c motor armatures assures practically vibrationless operation.

4. Where required, motor frames are designed to prevent dripping liquids and falling metal particles from entering the motor interior.

From coiled strip to finished tube, Crocker-Wheeler protected power is "always there" providing dependable service with minimum maintenance.

If you have an application where trouble-free motor operation is a "must", write for complete information on whatever type of motor you will need.

THIS YODER TUBE MILL IS EQUIPPED WITH THE FOLLOWING CROCKER-WHEELER POWER UNITS:

Direct Current Motors

4 — 15 hp — Cut-off
2 — 3/5 hp — Wash Machine
1 — 3/5 hp — Paint Machine
2 — 3/5 hp — Conveyor
2 — 3/5 hp — Cut-off Conveyor
1 — 150/200 hp — Forming Mill
1 — 20 hp — Pinch Roll
1 — 75/100 hp — Sizing Mill
1 — 30 hp — Leveller
1 — 40 hp — Trimmer
1 — 5 hp — Pinch Roll

Alternating Current Motors

1 — 7½ hp — Coil Box
1 — 7½ hp — Elevator
3 — ¾ hp — Pump Motor
1 — 15 hp — Cut-off
2 — 3 hp — Burring
2 — 3 hp — Runout
1 — 3 hp — Deburring
1 — 3 hp — Hydro test
1 — 3 hp — Loader
1 — 3 hp — Unloader
1 — 5 hp — Rotary Cut-off
3 — 5 hp — Stationary Cut-off
2 — 10 hp — Scrap chopper
2 — 5 hp — Electrode Rotator
2 — 1½ hp — Deburring
1 — 5 hp — Hydro test
1 — 2 hp — Hydro test
1 — 5 hp — Paint Machine
2 — 5 hp — Wash Machine
1 — 15 hp — Paint Machine

Motor-Generator Set

1 — 1000 KW — Motor Generator Set

CW-15

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A DIVISION OF JOSHUA HENDY IRON WORKS, AMPERE 20, NEW JERSEY

Branch Offices: BOSTON · BUFFALO · CHICAGO · CINCINNATI · CLEVELAND · DETROIT · LOS ANGELES · NEW YORK · PHILADELPHIA · PITTSBURGH · SAN FRANCISCO · WASHINGTON

SQUIRREL CAGE MOTORS · WOUND ROTOR MOTORS · DIRECT CURRENT MOTORS · GENERATORS · FLEXIBLE COUPLINGS

Harry W. Gleichert of the Columbia chemical division of the Pittsburgh Plate Glass Company has been appointed director of sales for the division. Mr. Gleichert has long been associated with the Columbia chemical division starting with the company in 1920 and being employed successively in the laboratory, development department, plant operation, technical service, and manager of special products of the sales department. In 1937 he was made assistant director of sales. Mr. Gleichert will be located at the executive sales office in Pittsburgh, Pennsylvania.

J. K. Keogh has been appointed manager of the Allis-Chalmers Manufacturing Company's Pittsburgh district office. Mr. Keogh joined Allis-Chalmers in 1904. He completed the company's training course for graduate students, later joining the service and erection department.

After returning from the army in 1919, Mr. Keogh joined the Pittsburgh district office as field engineer. His many years of work with steel manufacturers in the Pittsburgh area has made him a well known figure in the steel industry.

Nolan E. Watkins has been appointed director of safety in the Gary Sheet and Tin mill industrial relations department, Carnegie-Illinois Steel Corporation. Mr. Watkins has been associated with the company for the last 33 years and formerly served as assistant to the division superintendent of the tin mill. His other previous experience includes budgetary control, sheet mill finishing and standard costs.

Obituaries

Frank C. Angle, manager of the general machinery division field sales offices, Allis-Chalmers Manufacturing Company, Milwaukee, Wisconsin died October 25 after an illness of several months.

Mr. Angle, who was 45, has been field sales manager since 1944. He joined Allis-Chalmers in 1929 as a salesman in the Chicago office. In 1934 he joined the companies' San Francisco office and became manager of that office two years later. In 1943, Mr. Angle was appointed Pacific regional manager.

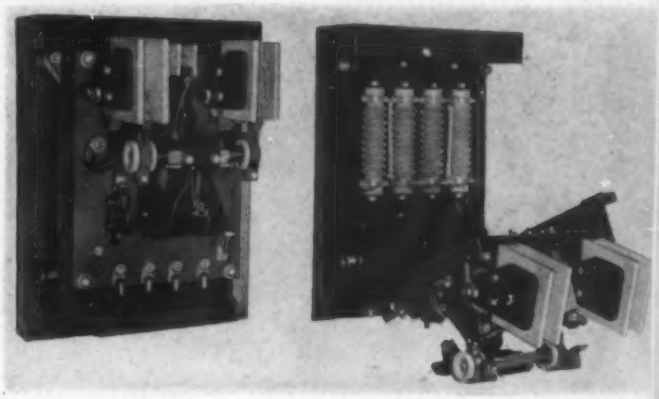
Mr. Angle was born at The Dalles, Oregon and received his B.S. degree from Oregon State College in 1923. He came to Allis-Chalmers after six years with the Elliot Company.

William E. Kane, founder and head of Kane and Roach died Thursday, October 11, 1945. Mr. Kane was known throughout the country for his brilliance in machine design, and has to his credit a long list of inventions among which are the cold roll forming machine, the straightener and the wrapping type bender, all of them widely used in industry. He also invented wheel drills, hydraulic presses, and other mass production tools. Mr. Kane was a deep student of archaeology, and made many trips to South America, Egypt and other lands.

OHIO

QUICK DROP MAGNET CONTROLLE

With arc suppressor and quick dro automatic for any class of materi



Closed **Open for Inspection**

Two main switches open circui in series. Reverse and quic drop are automatic. Master co tacts carry control circuits onl

The arc suppressor reduces th arc so it is not harmful or di agreeable. Contact tips are thu saved. Arc shields do not bur

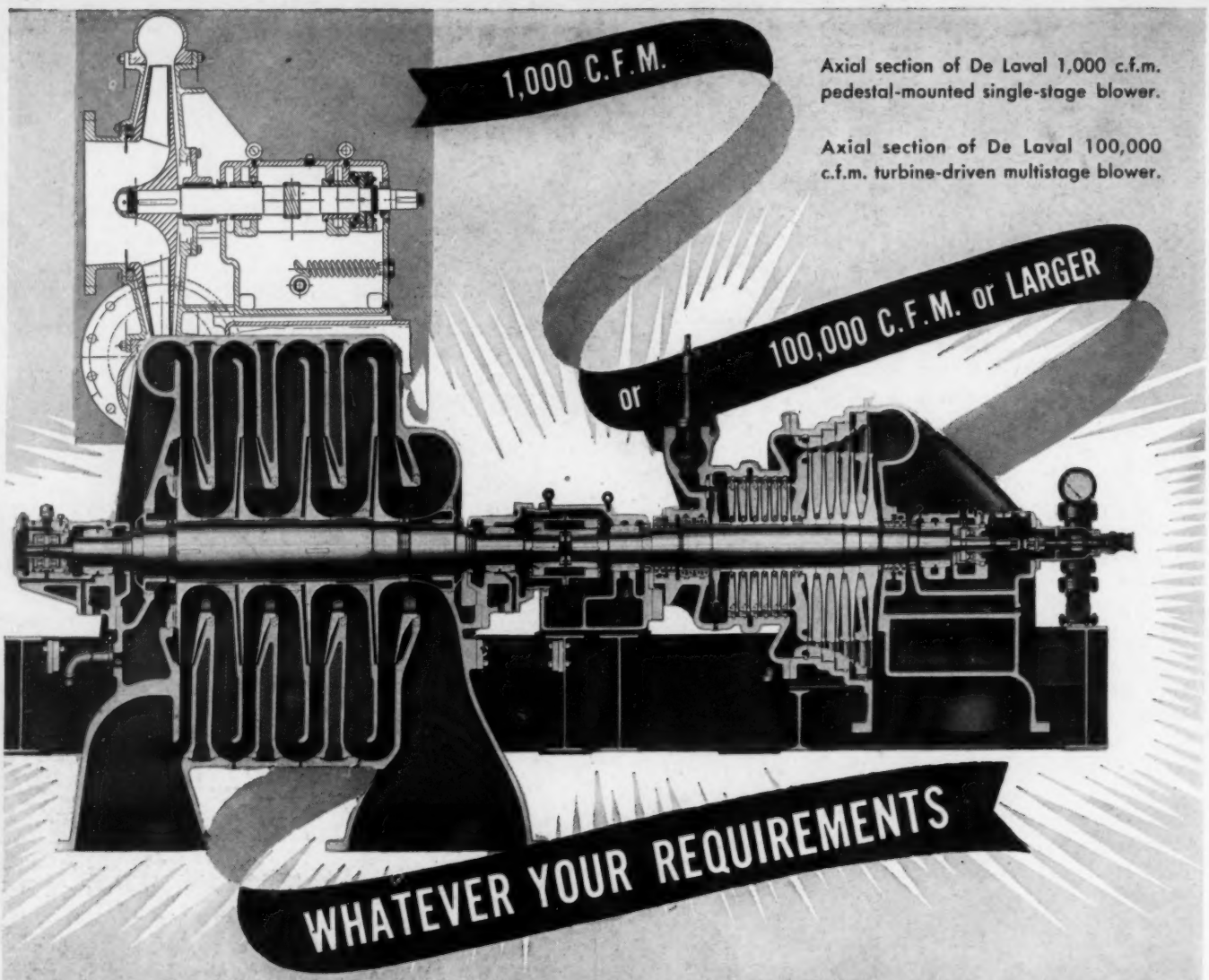
This controller makes possibl 6 or more lifts per minute whic is as fast operation as any w have ever observed in practic

●

OHIO reliable MAGNETS

The Ohio Electric Manufacturing Company

5907 Maurice Ave., Cleveland 4, O


1,000 C.F.M.
Axial section of De Laval 1,000 c.f.m. pedestal-mounted single-stage blower.
Axial section of De Laval 100,000 c.f.m. turbine-driven multistage blower.
or 100,000 C.F.M. or LARGER
WHATEVER YOUR REQUIREMENTS

DE LAVAL BLOWERS AND COMPRESSORS

will do the job!

De Laval blowers and compressors are available in all sizes for capacities up to 100,000 c.f.m. and above, and for pressures of from a fraction of a pound to 100 pounds per square inch and above.

For operations requiring the use of centrifugal blowers, compressors or exhausters, our engineering specialists are at your service for consultation.

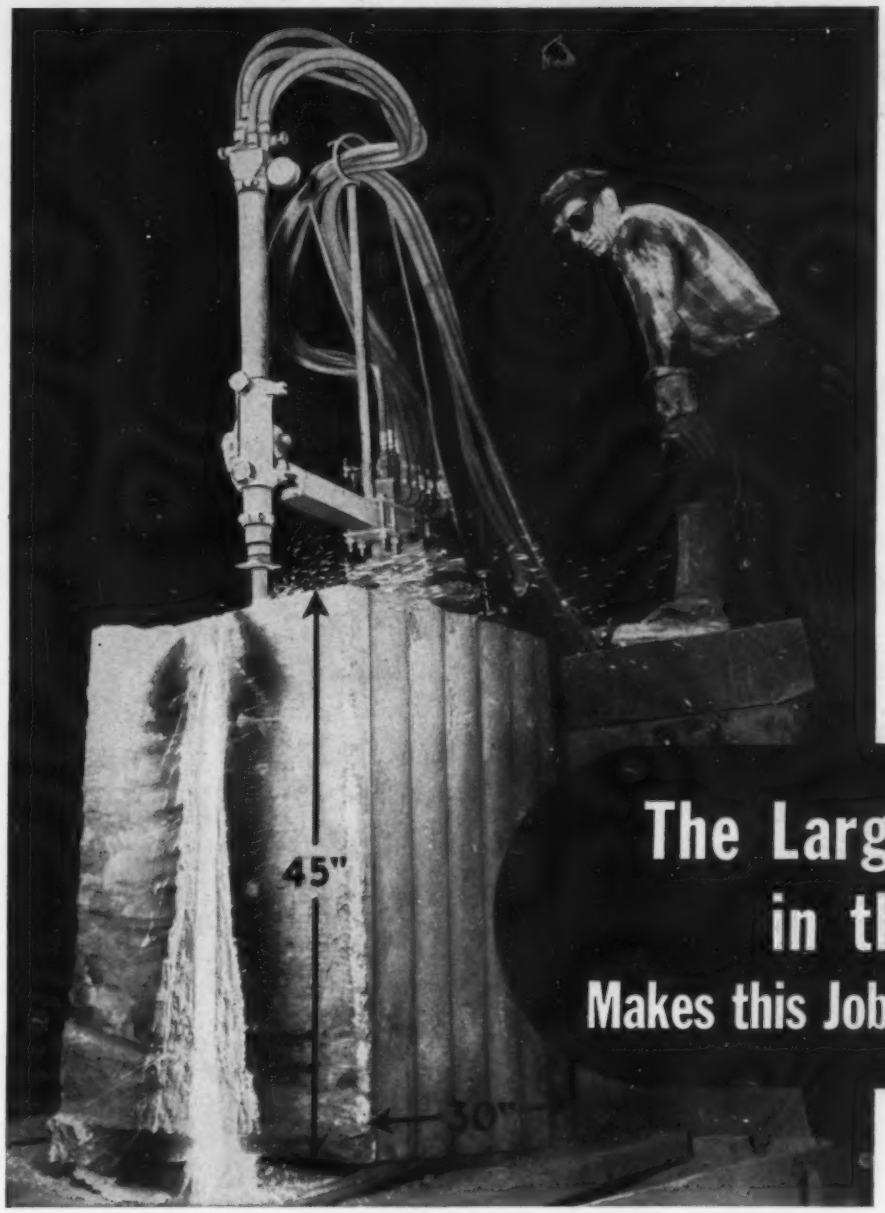
3829

TURBINES • HELICAL GEARS • WORM GEAR SPEED REDUCERS CENTRIFUGAL PUMPS • CENTRIFUGAL BLOWERS and COMPRESSORS • IMO OIL PUMPS

DE LAVAL

STEAM TURBINE COMPANY · TRENTON 2, NEW JERSEY

SALES OFFICES: ATLANTA • BOSTON • CHARLOTTE • CHICAGO • CLEVELAND • DENVER DETROIT • DULUTH • EDMONTON • GREAT FALLS • HAVANA • HELENA • HOUSTON KANSAS CITY • LOS ANGELES • MONTREAL NEW ORLEANS • NEW YORK • PHILADELPHIA PITTSBURGH • ROCHESTER • ST. PAUL • SALT LAKE CITY • SAN FRANCISCO • SEATTLE TORONTO • TULSA • VANCOUVER • WASHINGTON, D. C. • WINNIPEG



The Largest Blowpipe in the World Makes this Job as Easy as it Looks

It takes just **15 minutes** to slice through an ingot of this size. For eight hours a day, five days a week, this giant OXWELD C-45 oxy-acetylene blowpipe and another just like it are in operation at this mill slitting ingots for scrap.

IF YOU CAN USE A RAPID METAL-CUTTING METHOD...

If a fast, economical method for cutting heavy ingots, risers, or forgings, will increase efficiency of operations in your plant, get in touch with the nearest Linde representative. He will help you to determine if your job can be done better by methods developed by The Linde Air Products Company.

BUY AND HOLD UNITED STATES VICTORY BONDS

THE LINDE AIR PRODUCTS COMPANY

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OXWELD AND UNIONMELT SUPPLIES

The words "Linde," "Oxweld," "Prest-O-Lite," "Prest-O-Weld," "Purox," "Union," and "Unionmelt" are trade-marks of Union Carbide and Carbon Corporation or its Units.

HOW BAILEY CONTROLS INCREASE SAFETY

SAFE BOILER OPERATION

EXPLOSION HAZARDS REDUCED

1. Automatic Readjustment of fuel-air ratio insures proper mixture for safe efficient combustion.

2. Limit stops and accurate draft control protects against loss of ignition at low ratings.

3. Interlocks may be provided to trip out equipment upon failure of related units.

4. Purge interlocks insure safety in lighting-off.

OPERATORS FREE TO ACT

In emergencies control automatically carries on leaving the operating personnel free to concentrate on the cause of the emergency.

SAFE STEAM TEMPERATURE

Prime movers, superheaters, valves and piping are protected against excessive steam temperatures by superheat control.

NORMAL WATER LEVEL

Damage to turbines from water carry-over and to boiler tubes from low water is avoided by effective feed water control.

BOILER FEED PUMPS

Automatic by-pass control protects feed pumps at low rates of flow.

IN YOUR PLANT

There may be applications where Bailey Controls will improve safety, lower fuel and maintenance costs, and enable you to render better power service.

Call on your local Bailey engineer to make recommendations or write for Bulletin 15-C which describes Bailey Controls for Steam Plants. Bailey Meter Company, 1047 Ivanhoe Road, Cleveland 10, Ohio. In Canada—Bailey Meter Company Limited, Montreal.

A-93

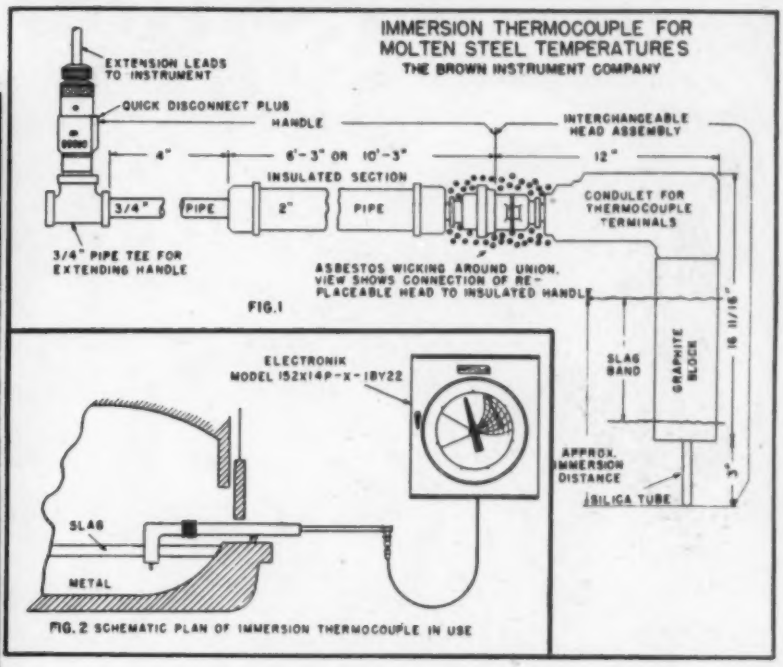
BAILEY METER COMPANY

1047 IVANHOE ROAD • • • CLEVELAND 10, OHIO

Controls for Steam Plants

COMBUSTION • PRESSURE
FEED WATER • LIQUID LEVEL
TEMPERATURE • FEED PUMPS

New System For Measuring Molten Steel Temperatures



The Brown ElectroniK Potentiometer — offering twice the sensitivity of any other potentiometer on the market — PLUS a new platinum thermocouple construction, makes possible temperature measurement of molten steel in electric arc and open hearth furnaces.

Operating on the "Continuous Balance" principle — which uses (instead of a galvanometer) a compact electronic unit to detect process temperatures with super sensitivity, speed, precision and ruggedness — the Brown ElectroniK provides closer control of melting and refining processes than has heretofore been possible.

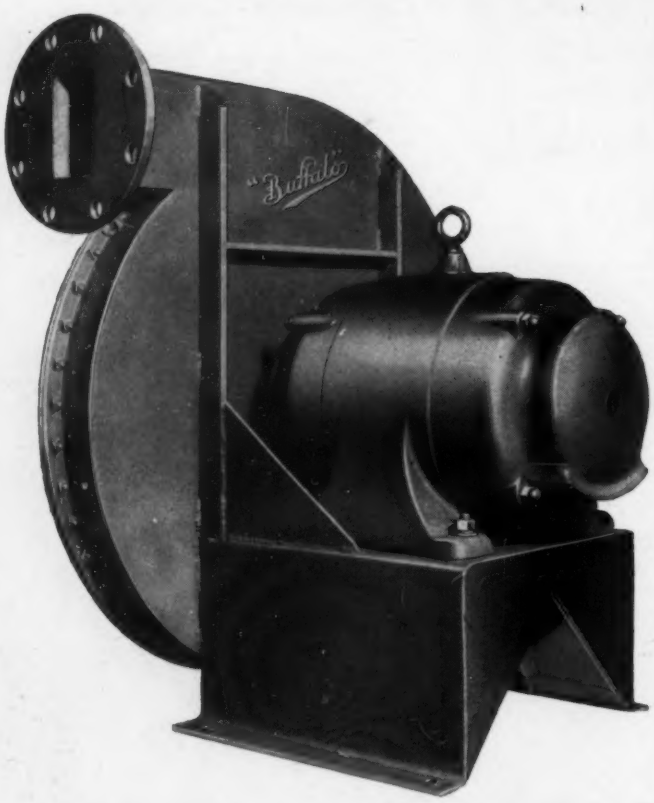
The platinum thermocouple assembly, specifically designed for bath temperature measurement, is a practical answer to this important steel making problem. It provides basic standards of accuracy, ease of maintenance and sound mechanical design.

Write for detailed information on this new Brown system. THE BROWN INSTRUMENT COMPANY, a division of Minneapolis-Honeywell Regulator Company, 4464 Wayne Avenue, Philadelphia 44, Pa. Offices in all principal cities. Toronto, Canada; London, England; Stockholm, Sweden; Amsterdam, Holland.

The operator of the new Immersion Thermocouple inserting the immersion head into an electric arc furnace at the Rustless Iron and Steel Corporation's plant, Baltimore. The head was immersed in the molten (stainless) steel for 45 seconds. Temperatures of the steel ranging from 2200 to 3200° F. were accurately recorded on a Brown ElectroniK Potentiometer.

BROWN *ElectroniK* POTENTIOMETERS

"Individual Blowers save money on Multiple Units"



Buffalo Type "CB" and "CC" Units are ideally suited for operation in steel mills, glass factories, metallurgical and chemical factories and wherever relatively small amounts of air are required at high pressures.

Operating economies with these "tailor-made" blowers make individual installations more satisfactory than a large central blower system.

Because Type "CB" and "CC" Units are built to fit the exact requirements of each application, peak efficiency can be obtained.

Write for Bulletin 3553 which gives details.

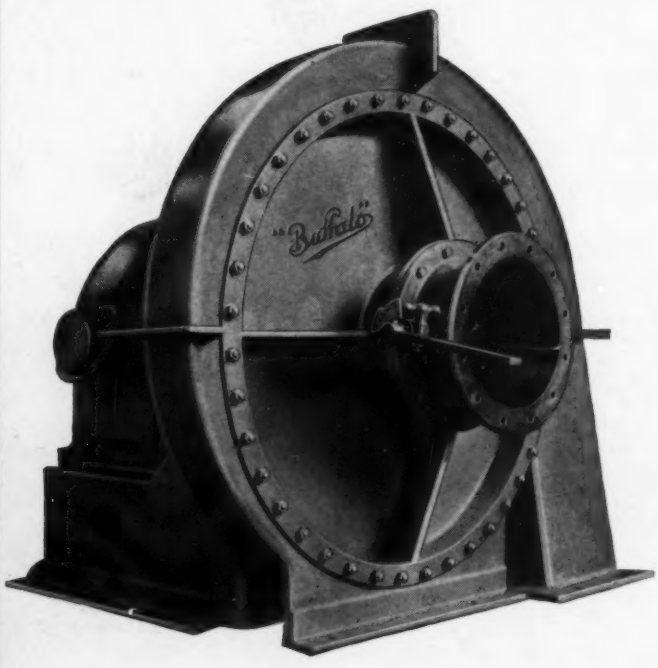
BUFFALO FORGE COMPANY

173 MORTIMER ST. - - BUFFALO, NEW YORK

CANADIAN BLOWER AND FORGE CO., LTD., KITCHENER, ONT.

These "CB" Blowers range in capacity from 200 to 5000 cfm, with pressure range from ¾ lb. to 2 lbs. per sq. in.

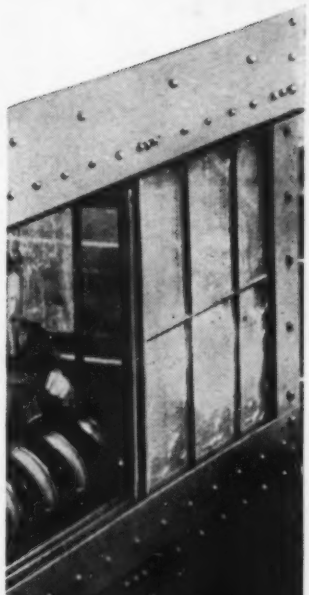
Single stage Type "C" centrifugal compressors for capacities from 4000 to 75,000 cfm at pressures up to 8 inches of mercury.



"Buffalo"

Hi-Pressure Blowers

NEW N·B·M BRONZE BEARINGS INCREASED TONNAGE 1200%



That's right—*1200%*. On a typical 36-inch Plate Mill—where fabric and babbitt had made ordinary records—N-B-M #200 Bronze Bearings lasted *12 times as long.*

What's more: the mill reports that one pair of N-B-M Bronze Bearings saved $500 in labor costs for bearing changes alone. Besides great economy, they assure: Less power consumption • Freedom from cut roll necks • More uniform gauge.

It will actually cost you *less* to install N-B-M castings. Why not send for one of our engineers today?

N · B · M

BRONZE AND COPPER CASTINGS

BLAST FURNACE COPPER CASTINGS • ROLL NECK BEARINGS • SLIPPERS • HOUSING NUTS
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NBM

NATIONAL BEARING

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PITTSBURGH NEW YORK

AMERICAN Brake Shoe COMPANY

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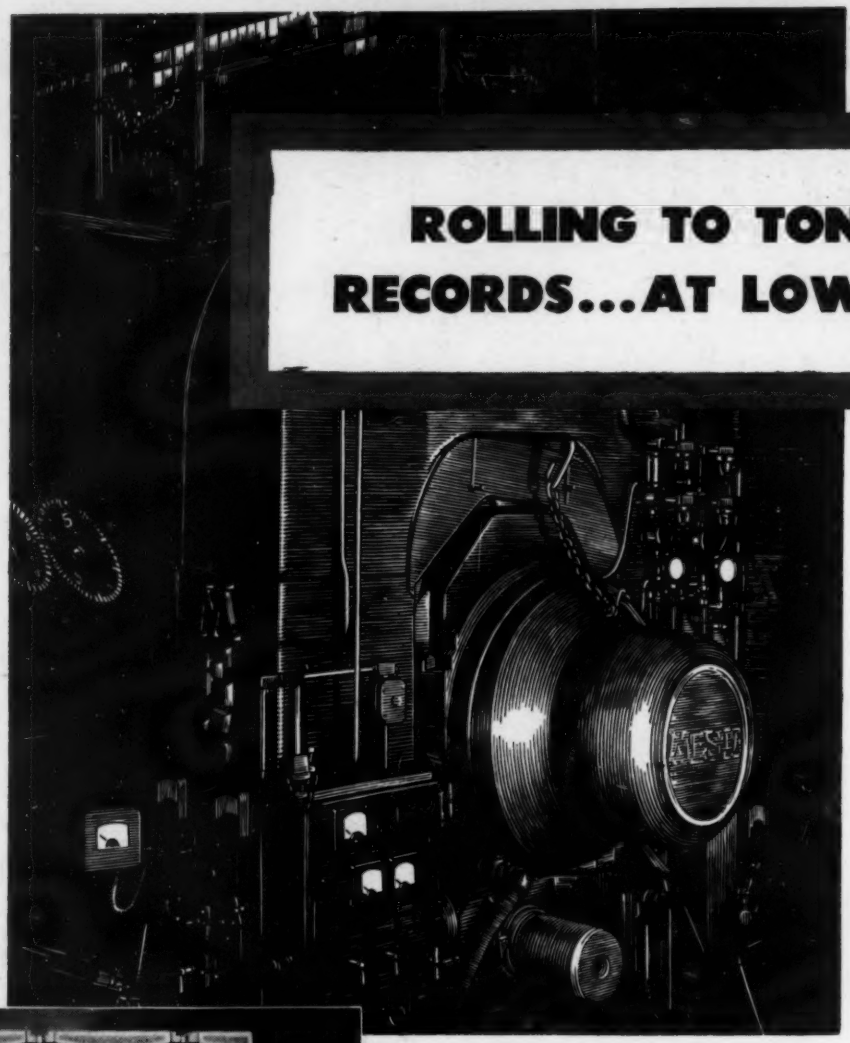
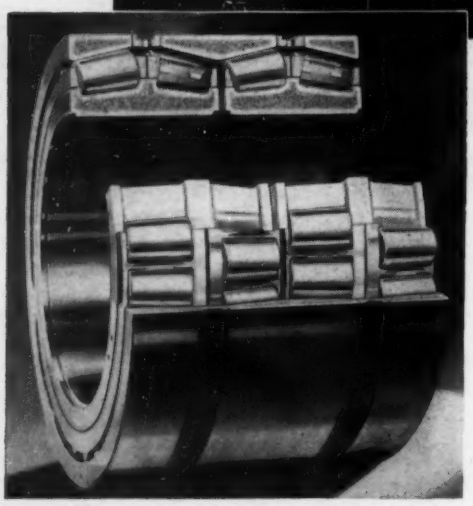
ROLLING TO TONNAGE RECORDS...AT LOWER COST





X-section and cutaway view of the Torrington 4-row Tapered Roller Bearing. For maximum roll neck diameters, bearings of all tapered types can be supplied with proportioned cross-section.

Engineered for unusually high resistance to wear, Torrington 4-row Tapered Roller Bearings provide the accuracy and sturdiness required for high speed roll neck applications and other heavy-duty jobs. The simple design of these high capacity bearings permits easy servicing and reduces costly maintenance time-out to a minimum, thus increasing production output.

Superior performance is an outstanding characteristic of Torrington Bearings in a wide variety of steel mill applications, such as work rolls, back-up rolls, edgers, reels, screwdowns, shears, pinion stands and many others.

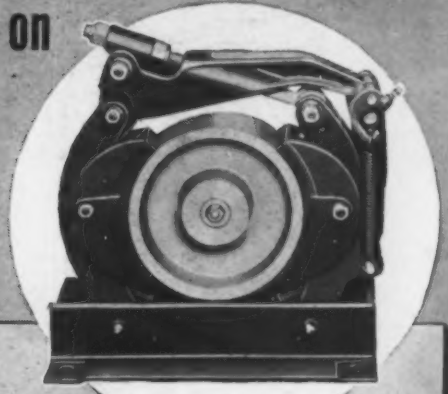
The advantages of specifying Torrington Bearings in *your* steel mill equipment are many, including actual dollar and cent savings in operational costs. Torrington's Bantam Bearings Division places at your disposal its wide experience in the design and construction of anti-friction bearings to meet specific requirements.

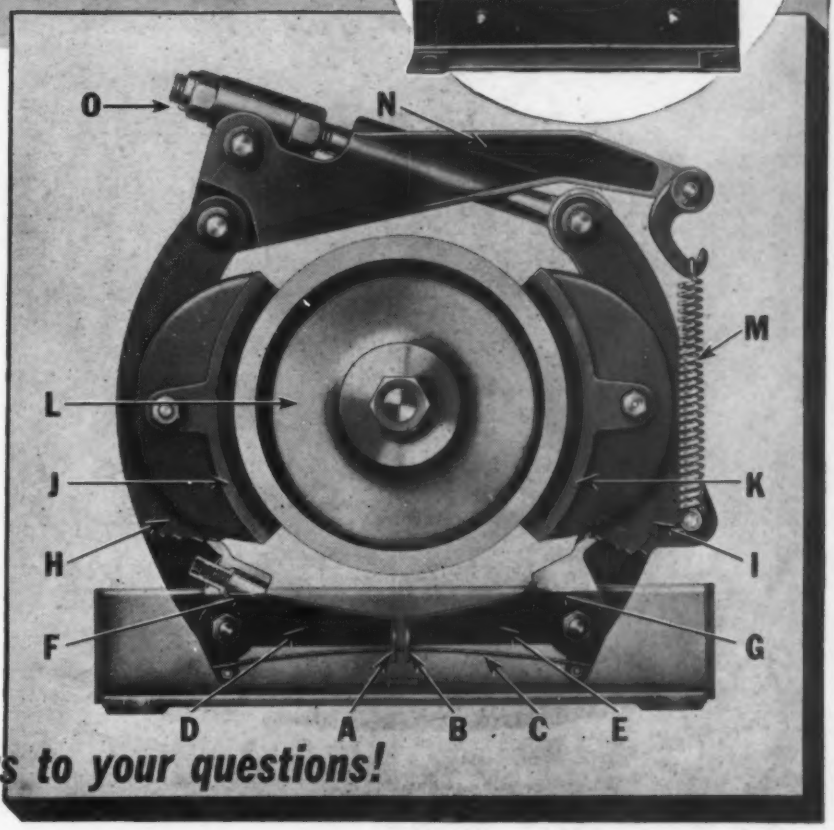
THE TORRINGTON COMPANY • BANTAM BEARINGS DIVISION
SOUTH BEND 21, INDIANA

TORRINGTON BEARINGS

STRAIGHT ROLLER • TAPERED ROLLER • NEEDLE • BALL

New Device Self-Centers Brake Shoes on Wagner Hydraulic Bridge Brakes





Prevents Shoe Drag . . .
(thus saving brake lining)

The new self-centering device on Wagner hydraulic bridge brakes will mean savings of money and time to the user. This new device prevents dragging of brake shoes (thus saving brake lining)

—and here are the answers to your questions!

QUESTION: *How does the Self-Centering Device work?*

ANSWER: It works on the same principle as the swinging door—a spring returning the door to the same starting point, irrespective of direction of swing. When brake is released, spring M pulls down brake lever arm N, causing shoe arms H and I to be spread apart to clear brake wheel L. Spring C assures equal movement of both shoe arms, thus preventing either shoe from remaining in contact with brake wheel L.

Spring C presses equally against contact points A and B (which are equally distant from center of spring), moving equalizing arms D and E upward until they are in line with each other. Equalizing arms D and E press against shoe arms H and I at contact points F and G—and as the pressure is at all times equal, the shoe arms are moved out (away from the brake wheel) equal distances, carrying both shoes J and K equal distances away from the brake wheel L. Neither shoe can drag.

QUESTION: *Does Lining wear affect the self-centering device?*

ANSWER: No. When brakes are applied, shoe arms H and I move toward the brake drum L. Contact points F and G move downward, pressing equalizing arms D and E downward against spring C at contact points A and B. As the brake lining wears, contact points F and G move relatively farther, pressing equalizing arms D and E farther down. Spring C will be depressed to a greater degree—but when the brake pressure is released, spring C will bear equally against points A and B, and as explained above both shoe arms will be moved away from the brake drum equal distances, and the shoes are again centered as before irrespective of change in lining thickness.

QUESTION: *Are adjustments necessary to keep self-centering device operative?*

ANSWER: No, except when installed. This is done at contact point F by means of a set screw which is locked after shoes have been accurately centered. Wear factor at contact points is so insignificant that no appreciable change in centering of shoes will occur.

QUESTION: *How are shoes adjusted to compensate for lining wear?*

ANSWER: At point O where a "one-point adjustment" repositions shoes to compensate for lining wear.

Write for Complete Information

I45-12

WAGNER PRODUCTS serving industry:
AIR BRAKES • BRAKE LINING • HYDRAULIC BRAKES • INDUSTRIAL BRAKES • INDUSTRIAL BRAKE CONTROLS • MOTORS • NoRel • TACHOGRAPH (Recording Speedometer) • TRANSFORMERS

Wagner Electric Corporation

ESTABLISHED 1891

6483 Plymouth Avenue, St. Louis 14, Mo., U. S. A.

In Canada: Wagner Electric at Leaside, Ontario

ELECTRICAL AND AUTOMOTIVE PRODUCTS

It's Costly To Remove Oil From Steel Sheets

TRADE MARK REGISTERED

NON-FLUID OIL

IN U.S. PAT. OFFICE & FOREIGN COUNTRIES

Prevents this cleaning problem, and you too—like other Steel Mills—can avoid it by using NON-FLUID OIL. Drip-less and waste-less [NON-FLUID OIL stays in bearings and lubricates dependably until entirely consumed.

Metal is protected from oil showers by the use of NON-FLUID OIL, particularly in overhead bearings. Cost of lubrication is reduced as NON-FLUID OIL lasts longer, so needs less frequent application.

Write for Descriptive Bulletin.

NEW YORK & NEW JERSEY LUBRICANT CO.

292 MADISON AVENUE NEW YORK 17, N. Y.

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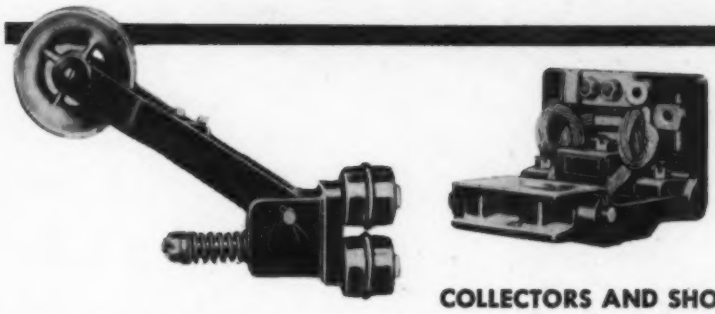
NON-FLUID OIL is not the name of a general class of lubricants, but is a specific product of our exclusive manufacture.

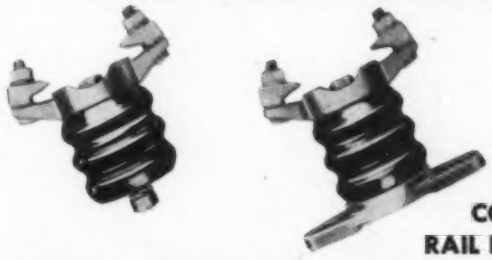
Reconversion calls for . . .

TRAVELING ELECTRICAL CONTACT and HEAVY FEEDER SYSTEM

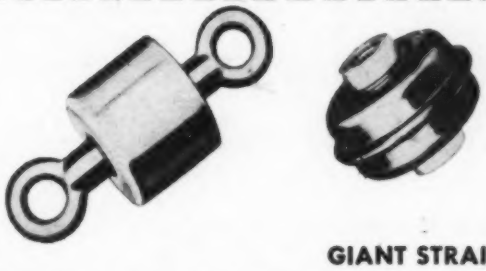
. . . Materials



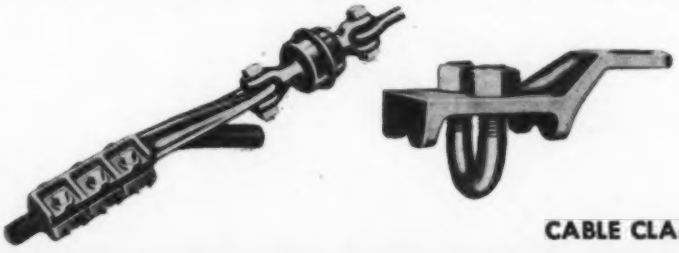
COLLECTORS AND SHOES



CONTACT RAIL INSULATORS



GIANT STRAIN INSULATORS



CABLE CLAMPS

When reconverting your haulage system don't overlook this complete line of contact rail material utilizing either rails, angles or wire as a conductor including numerous types of insulators for either under-running or over-running operation. You may also select from many types of current collectors including Junior, Universal and Pantagraph styles and contact rail shoes.

The Keystone line also includes numerous types of clamps and insulators for the insulation, suspension and dead-ending of heavy feeder cables.

These products are widely used in most large steel mills, being thoroughly proved in service. The complete catalog illustrated above will be very helpful to all interested in the construction or maintenance of cranes or feeder systems.

ELECTRIC SERVICE MANUFACTURING CO.

Former Name—Electric Service Supplies Co.

17th & CAMBRIA STREETS • PHILADELPHIA 32 • PA. • Branches in Principal Cities

Designed for Rolling
SPECIAL STEEL . . .

The new Birdsboro Metal roll is designed specially for rolling special steels. If you are experiencing difficulty in rolling aircraft quality steel, alloy steel bars, corrosive steels or non-ferrous metals, try Birdsboro Metal rolls and get higher tonnages, less reduction per dressing, added toughness and roll strength. Call Birdsboro today!

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BIRDSBORO STEEL FOUNDRY & MACHINE CO • BIRDSBORO, PA.

BIRDSBORO
ROLLS

IRON AND STEEL ENGINEER INDEX FOR 1945

Herewith is presented the index of all authors and papers published in the IRON AND STEEL ENGINEER for the year 1945

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A. I. S. E. DISTRICT SECTION MEETINGS

BUFFALO DISTRICT — Tuesday, January 8

"Rolling of Steel for Saws," by Percy J. Britt, Assistant Superintendent Simonds Saw and Steel Company, Lockport, New York.

CHICAGO DISTRICT — Tuesday, January 8

"Lighting Systems, Their Maintenance and Improvement," by B. Fantone, Engineering Department, Carnegie-Illinois Steel Corporation, Gary, Indiana.

"Dynamic Balancing of Rotating Machines," by A. G. Gebhard, Master Mechanic, Illinois Central Railroad, Chicago, Ill.

"Electrical Installation Innovations" Inland Steel Company, East Chicago, Indiana.

DETROIT DISTRICT — Tuesday, January 22

"Reversing Versus Tandem Mills," by M. D. Stone, Manager Development Department, and G. G. Beard, Vice President, United Engineering and Foundry Company, Pittsburgh, Pennsylvania.

PHILADELPHIA DISTRICT — Saturday, January 5

"Trends in Electrical Equipment for Steel Mills," by G. E. Stoltz, Manager of Steel Mill and Metal Working Section, Westinghouse Electric Corporation, East Pittsburgh, Pennsylvania.

"War Development and Steel," by F. Mohler, Engineer, Steel Mill Section, Industrial Engineering Section, General Electric Company, Schenectady, New York.

PITTSBURGH DISTRICT — Monday, January 14

"Radio Communication As Applied to Switch Yard Operations", by G. H. Phelps, Engineering Department — Radio Division, Westinghouse Electric Corporation, Baltimore, Maryland.

BIRMINGHAM — January 28

"Automatic Acceleration for Direct Current Motors," by Edward J. Posselt, Supervisor Engineer, Cutler-Hammer, Inc., Milwaukee, Wisconsin.

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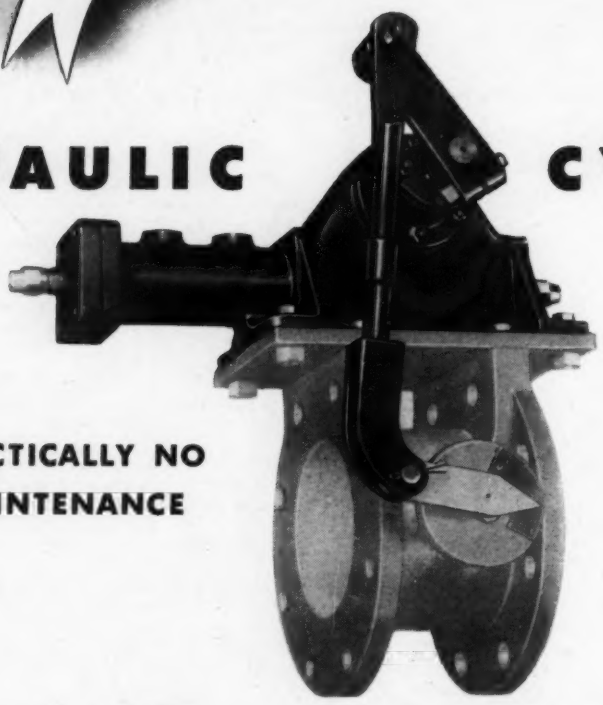

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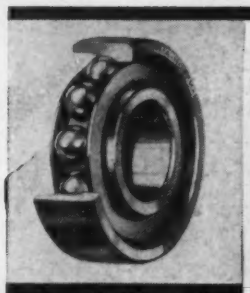

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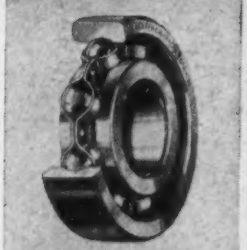

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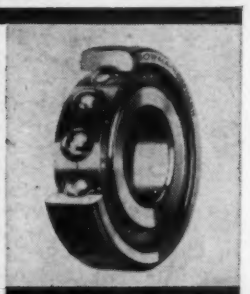

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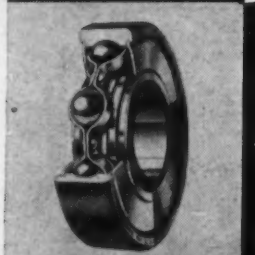

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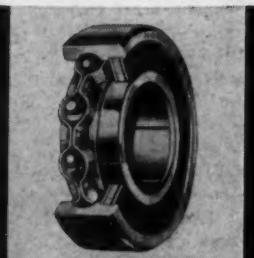

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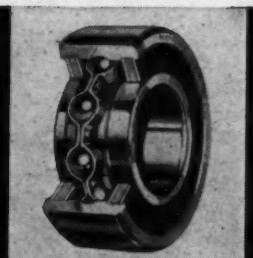

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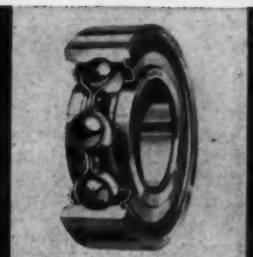

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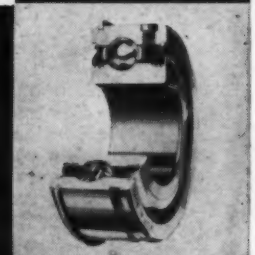

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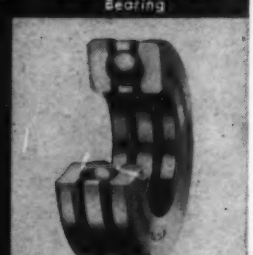

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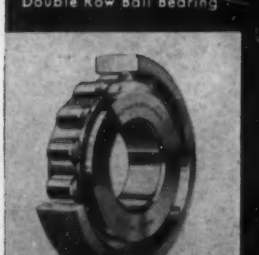

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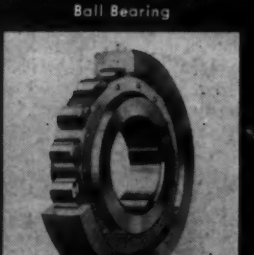

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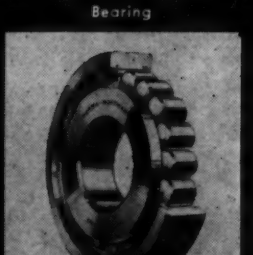

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